Popular Astronomy.

Vol. VIII. No. 10. DECEMBER 1900. Whole No. 80.

THE ORBIT OF THE LEONID METEORS.

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During the last year and a half, some astronomers have expressed opinions, with more or less assurance, that the path of the Leonid stream of meteors has been so changed, that we may no longer hope for such grand showers as were seen in 1866 and notably in 1833. Particular attention was called to this possibility and even probability, by a paper presented before the Royal Astronomical Society, March 2, 1899, by G. Johnstone Stoney and A. M. W. Downing, an abstract of which was printed in *The Observatory*, for May, 1899. In that paper it was said that Professor J. C. Adams' object in investigating the Leonid orbit was to determine the shift of the nodes of the orbit due to the disturbances by the planets and to compare the calculated amount with that obtained by Professor H. A. Newton, of Yale College, from a study, which he had made, of observations at intervals during the last thousand years. Professor Adams, of England, gave attention to this interesting piece of mathematical work about 30 years ago, using what is known as the method by Gauss for computing perturbations. Mathematicians esteem it a method of great elegance, because it "furnishes the average amount of each perturbation on the supposition that the periodic times of the disturbed body and the disturbing planet are incommensurable, so that in the course of time, the two bodies present themselves in every possible position in relation to one another." It will readily be seen that these conditions could be only imperfectly fulfilled in the short period of 1000 years from which time all available observations were secured, and so results obtained from the most excellent of methods would be incomplete for obvious reasons.

The three planets which influenced the path of the Leonids most during the last period of revolution of the stream were Jupiter, Saturn and Uranus. If we remember that 14 revolutions of Jupiter equal 5 revolutions of the Leonids within about one-fifth

NEW ALLEGHENY OBSERVATORY.
(Photographed from Architect's Plans.)

of a year; that 2 revolutions of Uranus equal the same time within two years, and that 9 revolutions of Saturn equal 8 of the Leonids within a fraction of a year, it will be easy for any reader to understand how the attraction of these great planets when near the thickest part of the stream will certainly change its course.

Now, since these cycles of planetary attraction have been several times repeated during the 1,000 years already referred to, it is known that the points of intersection of the Earth's orbit with that of the Leonids has oscillated about a mean value of the advance of the node, so that predictions of showers dependent on this mean motion have usually varied several hours from the times of their actual occurrence. In the article referred to, one instance is mentioned in which the computed time was twenty-six hours later than the appearance of the shower. This occurred in the year A. D. 1533. Some computations for the present century have furnished results showing as great a difference between the forecast and the actual shower, as in this instance, but, in the opposite direction.

From these and other facts like them it must be evident that the problem of determining the exact position of the orbit of the Leonids for any date is a very difficult one. Astronomers are fully aware of this, and they have given earnest attention to its study for some years past, and they are still at work on the details of the problem which seem almost endless in kind and variety.

It may be instructive to the ordinary reader to have a few more points in outline to get a fuller view of the nature and extent of the problem. In order to predict the coming of a great Leonid shower satisfactorily, it will be necessary to know the actual amount of the perturbations in each revolution of the swarm of meteors, and also for meteors occupying various stations along the path of the stream, so as to determine its course in space as definitely as possible. The dense part of the stream is called the ortho-stream, which means the great body of the Leonids travelling around the Sun, in nearly a compact swarm of such length that it requires about three years for the whole train to pass the point of intersection which the Leonid orbit makes with that of the Earth; but on account of the inclination of the two orbits the time that is required for the Earth to pass through the ortho-stream each year is only five or six hours. There are also other Leonid meteors that have fallen behind, or are in advance of the parent stream, so that all parts of the

great orbit are probably more or less occupied by astray members of the group. This stream which is wider and less dense than the other is called the clino-stream. The clino-Leonids are comparatively few and are seen at the usual time in November every year. The ortho-orbit is the mean path of the ortho-stream, and the clino-orbit which is obtained by the study of clino-Leonids every year is the mean path of this diffuse clino-stream. The clino-Leonids are so scattered that they produce only feeble Leonid showers every year, but they last for several days, instead of a few hours as is true of the great ortho-showers. In consequence of irregularities in the stream of the ortho-Leonids the ortho-orbit does not generally cross the Earth's orbit at points in successive periods which show a regular progressive change of node, but irregular ones as before indicated. Add to this the uncertainty and lack of agreement of the mean of the clino-paths of the clino-Leonids, and the wonder is that astronomers can do scarcely anything at all in securing what may be called a definitive orbit of the Leonids, much less determine well the dates of great showers that last 6 hours at intervals of 33 years.

But these and other great difficulties which appear in calculating the perturbations of the planets do not discourage the patient astronomer. His work goes on, though he does not expect the end of it for centuries; he will still earnestly seek the best knowledge he can get from time to time as the years go on, waiting for better and fuller knowledge when it can be secured by the aid of more exact and more comprehensive data.

The work in hand at the present time toward getting a better knowledge of the path of the Leonids is largely concerned in a study of perturbations. This has been undertaken by computing the actual perturbations of a definite part of the ortho-stream over the whole of one revolution in the orbit as computed by Professor Adams, of Cambridge, England, in November, 1866, until January, 1900, when the same part of the stream would again reach the Earth's orbit. Two things aid us now, probably, which were not taken into the account when Adams computed the orbit a third of a century ago. One is the aid of photography in determining the radiant, and the other is the influence of the Earth in deflecting the meteors that are observed.

The aid that photography can give under favorable circumstances must be considerable, although it must be confessed that very little assistance was gained from this source in 1899, because of moonlight chiefly; and so far as we have heard, the same

is true this year. Not a single meteor trail was caught in the region of the radiant on the plates exposed at Goodsell Observatory on the morning of November 15 between the hours of 3 and 5.

From these facts it will be seen readily, that the Adams orbit can only be considered as an approximate one, and hence present and future work on this problem must so use it.

The authors, whose names are mentioned at the beginning of this article, have published a brief paper in *Nature*, Nov. 1, 1900, indicating some interesting results in regard to the probability of a Leonid display in November, 1900. It will interest our readers to compare the probable conclusions reached by G. Johnstone Stoney and A. M. W. Downing with the observations of the Leonids made last month. The article is titled "The Leonids—a Forecast" and is as follows:

"In the *Proceedings* of the Royal Society for March 2, 1899 (vol. lxiv. p. 403), will be found an account of the perturbations suffered since 1866, November 13, by the Leonids which in that month intersected or passed close to the Earth's orbit. This position in the meteor stream may be called station *A* (Fig. 1).

We have since investigated the principal perturbations affecting two other points in the stream, viz., the station *z*, which intersected the Earth's orbit 360 days earlier, *i. e.* in November, 1865, and the station *B*, which intersected the Earth's orbit 360 days later, *i. e.* in November, 1867.

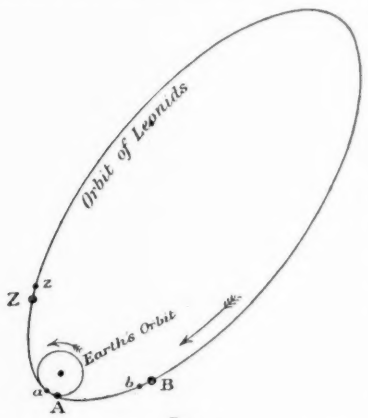


FIG. 1.

We therefore now know the principal perturbations which during the last revolution of the meteors have affected three points, *z*, *A* and *B*, situated along an orbit (Adams's orbit) which, at the commencement of the revolution, lay within the stream.

The full results of the investigation will not be ready for publication till after the time when the Leonid shower of this year is due, and on this account it has been thought expedient to publish beforehand such of the results as have special reference to it.

A point in the stream which in 1867 lay along Adams's orbit between *A* and *B*, but nearer *B*, and which we may call the point

b, will this year reach its descending node simultaneously with the Earth. This will happen approximately on 1900, November, $15^d\ 3^h$ Greenwich mean astronomical time.

Unfortunately, the orbit of a meteor situated near point b in the stream, instead of intersecting the Earth's orbit as it did in 1867, will now pierce the plane of the ecliptic in a point which lies about 0.018 nearer the Sun. Now, 0.018 of the Earth's mean distance from the Sun is 1,674,000 miles; so that, of the meteors which in 1867 intersected the Earth's orbit, those which will come nearest to the Earth in the present year will not approach it nearer than a million and six hundred thousand miles.

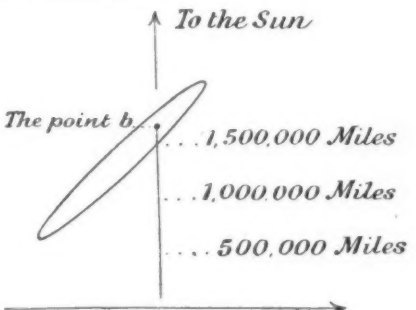


FIG. 2.

It is known from the duration of the great showers that the width of the ortho-stream, if measured in the direction which is parallel to the Earth's path, is only about 300,000 miles; but there is reason to believe that the Leonids entered the solar system under conditions which have made the section of the stream much longer than it is broad, so that its trace upon the plane of the ecliptic is something like what is represented in Fig. 2. The longer axis of this cross section lay originally along the radius vector from the Sun, but perturbations have acted on the Leonids for nearly 1,800 years of such a kind as have probably caused the section of the stream to incline in the direction represented in the figure.

If the section is long enough to reach the Earth's orbit, we shall have a great meteoric shower this year. It is, besides, just possible that a sinuosity in the stream may so displace a part of the section as to bring it sufficiently far out. But neither of these seem likely to have happened; so that the present investigation does not raise any hope of a great shower this year.

If, contrary to our expectation, the axis major of the section proves to be long enough to reach the Earth's orbit, the consequent shower of ortho-Leonids is likely to occur several hours—possibly more than a whole day—earlier than

1900, November, $15^d\ 3^h$

The number of hours by which it will precede that epoch depends upon the angle which the axis major of the section makes with the radius vector from the Sun—an angle which is at present unknown. If there is this year a shower of ortho-Leonids, the time at which it occurs will enable us to determine this important datum.

Station *a* in the stream (see Fig. 1) intersected the Earth's orbit in 1866, but after completing a revolution it passed the Earth in November of last year at a distance of some 1,300,000 miles; and *z*, the corresponding point for the preceding year, which also intersected the Earth's orbit in 1865, was on its return distant from the Earth in November 1898 by about 960,000 miles. It thus appears that the displacements of the meteoric orbits which have been brought about by the perturbations of the last thirty-three years suffice to have prevented the meteoric orbit from now intersecting the Earth's orbit. This accounts for our not having had any great shower in either of the last two years, and unfortunately the conditions seem still more unfavorable in the present year.

Nevertheless, as there is always a possibility that one or the other of the contingencies mentioned above may carry a part of the ortho-stream out as far as the Earth, and as we have no means of ascertaining whether those contingencies have arisen, it is desirable that preparation shall be made for adequately observing the shower, if it should unexpectedly come.

The perturbations during the last revolution which have for the present carried the ortho-stream of Leonids so far from the Earth's orbit, belong to the class of perturbations which act at different times with equal effect in opposite directions; so that there is reasonable ground for expecting that further perturbations must at some future time bring this remarkable stream back to the Earth's orbit. It would be possible to ascertain when this will happen, by an investigation carried over a sufficient time forward upon the same lines as those which we have pursued."

NOTE ON THE DOUBLE STAR, β 107.

S. W. BURNHAM.

FOR POPULAR ASTRONOMY.

In POPULAR ASTRONOMY for January, 1899, I called attention to the decided discrepancy in the positions of this and other stars in the field as compared with the positions given in the *D. M.*, and

gave diagrams from recent micrometer measures, and from the meridian places in Argelander showing the relative positions of the several stars according to these authorities. From this it appeared to be impossible to identify with absolute certainty the stars in the one with those of the other. In *A. N.* 3652 Kreutz has a note upon this subject, and has given the positions in right ascension and declination from my measure in 1898, and compared them with the corresponding positions of the *D. M.* At first glance it would appear that the two sets of places of four of these stars were after all practically identical, with one star wanting altogether. The fact is, however, that these places give exactly what was much better shown for the purpose of comparison in the diagrams referred to, and the apparent change in some of these stars still remains unaccounted for, and particularly the stars designated in my measures as *D* and *F*.

I have suggested in view of the general accuracy of the *D. M.* positions that this change might be due to a considerable proper motion of some one or more of these stars, and therefore connected them by a series of measures with the double star *A*. At my request Barnard repeated these measures in 1899, and I have re-observed them this year.

These results are as follows:

		A and *C*		
1898.73	336°.2	46″.95	2*n*	*β*
1899.82	336 .7	46 .83	2*n*	Bar
1900.71	336 .7	46 .78	2*n*	*β*
		A and *D*		
1898.73	146°.6	50″.27	2*n*	*β*
1899.82	146 .6	50 .30	2*n*	Bar
1900.71	146 .6	50 .32	2*n*	*β*
		A and *E*		
1898.76	171°.2	113″.78	1*n*	*β*
1899.82	171 .0	113 .48	2*n*	Bar
1900.71	170 .9	113 .55	2*n*	*β*
		A and *F*		
1898.76	113°.9	150″.44	1*n*	*β*
1899.82	113 .8	150 .32	2*n*	Bar
1900.71	113 .9	150 .49	2*n*	*β*

Although the interval is too short for the detection of a small movement in space, the close agreement of all the measures makes it extremely probable, if not certain, that the discrepancy in question cannot be explained by the proper motion of any one of these stars, and that the apparent change of the star *D*, which

appears to be No. 96 of the *D. M.*, is due to errors in the meridian observations. All of these stars are wanting in the *A. G.* Catalogue, and are not included in any other star catalogue so far as I have been able to find.

It is very probable, as suggested by Kreutz, that the double star *A* is identical with No. 94 of the *D. M.*, and this is confirmed by the comparison I have made of *A* with a south-preceding star, No. 85 of the *D. M.* The catalogue difference of declination agrees with that shown by recent measures, and the same is true of *E* and No. 97. It is therefore safe to say that the stars, *A*, *C*, *D* and *E* are respectively Nos. 94, 93, 96 and 95 of Argelander. Further measures are necessary to show the character of the change in *AB*.

The 40-inch shows that the star *E* has a 16^m companion 8″.61 distant in the position-angle of 139°.1.

THE PROPER MOTION OF β 182.

S. W. BURNHAM.

To this close pair has been assigned a somewhat remarkable proper motion for a star which is fainter than eighth magnitude. The several determinations of this movement are:

Romberg	1″.297	in 200°.4
Radcliffe	1 .331	in 202 .4
Porter	1 .302	in 201 .2

The last named value is probably the most accurate since the interval is considerably longer. It is catalogued as Wesse XXIII 175 and S. D. (14°) 6437. In the latter it is rated 8.2^m.

In order to test the correctness of this movement by a method independent of meridian observations, I measured in 1898 a 12.5 star from the close pair with the Yerkes refractor. This was the nearest star which could be readily measured with that aperture. I have recently re-measured this star, and these observations, with an intermediate set of measures by Barnard, are as follows:

1898.66	79°.9	68″.04	2*n*
1899.75	78 .5	68 .66	3*n*
1900.72	77 .5	69 .55	3*n*

It will be seen that the change in the position of the small star corresponds to the proper motion of the close pair. With the proper motion given in the Cincinnati Catalogue and the first set of measures in 1898, the computed position of small star for 1900.72 is 78°.0: 69″.47, which is practically identical with the observed place from the micrometrical observations.

The principal star is a close pair of nearly equal components, the present distance being about 0″.7. The observations indicate very slow retrograde motion in angle, with some diminution in the distance. Of the physical relation of the components there is no question, but the period is probably long. The facts cited suggest the comparative nearness of the system, and indicate that it may be a good subject for parallax observations.

AMONG THE STARS.

EDWARD S. HOLDEN.

The achievements of astronomy during the nineteenth century have been little short of marvelous. Not only have the classic methods of research been expanded and developed, but in the latter half of the century new instruments of unexpected power have been perfected and results obtained by their use in fields utterly closed to the astronomers of a hundred years ago.

Mathematical analysis reached a high state of perfection in the researches of Laplace and Lagrange at the century's beginning; the labors of profound analysts like Gauss, Adams, Le Verrier, Gylden, Hill, Newcomb and many others have placed mathematical astronomy on an entirely new footing.

It is impossible in a popular paper to give any account of the triumphs of mathematicians. It must suffice to say that the advances in the theory of the motions of the heavenly bodies are as important and far reaching as the results obtained by the spectroscope, the photometer and the photographic plate. One signal result stands out as a brilliant type of the power of analysis.

The planet Neptune was discovered with the telescope in 1846 in consequence of laborious calculations by Le Verrier, (and Adams) upon the materials of the planet Uranus. Uranus had been discovered by chance by Sir William Herschel in 1781. A body of unusual appearance was seen in his telescope. Examination showed that it was a major planet revolving about the Sun in eighty-four years. Careful observations gave the shape and

size of its orbit. Calculations of the perturbing forces exerted by the other known major planets—Mercury, Venus, the Earth, Mars, Jupiter, Saturn—showed that its course in space would be along a certain line if these planets, and only these, affected its motion.

Renewed observations showed very slight, yet obvious, deviations from the predicted course. It occurred to several astronomers—to Arago, Bessel, Struve, Le Verrier, Adams—that these deviations were produced by the attraction of a major planet as yet unknown. Sir John Herschel wrote of the new planet a few weeks before its discovery in memorable words: "We see it as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far-reaching line of our analysis with a certainty hardly inferior to ocular demonstration." The extraordinarily complex problem of inverse perturbations was worked out by Le Verrier and by Adams and the place where the new planet would be found was foretold. When the telescope was directed to the predicted place the unknown planet was there; the mathematician, in his study, had directed the observer's telescope. Other achievements of the same order of merit, though far less striking, have distinguished the present century.

In the mathematical processes relating to spherical and to practical astronomy, also, this century has made its mark in history. Bessel, Struve and their successors in Europe and in America have reconstructed these branches of the science from the foundations. Every pupil in our colleges is now familiar with the highest refinements of observation and calculation; and the principles of instrument-making have been carried well nigh to perfection.

In some departments the instruments furnished are so perfect that the outstanding errors of observation are due chiefly to the human being who uses the apparatus, not to the apparatus itself. The distances of the Sun and many of the stars have been fixed with exactness. Telescopes are now made of great size and power. In 1824 Sir John Herschel became possessed of a very good refractor of five inches aperture, then the largest of its kind in the world. An instrument of equal power is now attached alongside the thirty-six inch telescope of the Lick Observatory to serve as a mere finder—like the sights of a rifle—to direct the giant tube of the main instrument.

Reflecting telescopes too, have been much improved, though not greatly increased in size, since the days of the elder Herschel. Well-equipped observatories are now scattered all over the earth.

The heavens are assiduously watched by professionals and by amateurs in all the length and breadth of the globe, and no change of importance can take place without being detected—perhaps by photography—and reported by the electric telegraph to every interested watcher in all the continents.

The advent of photography as the handmaid of astronomy marks a distinct advance in the processes of observation. The sensitive plate partially records all rays of light that fall upon its surface. Such a plate directed at the heavens shows thousands upon thousands of stars, each registered in its proper position and of its proper brightness. A second plate taken upon a succeeding night records all changes, either of position or of brilliancy. It is in this way that new minor planets are discovered (by their change of position), new variable stars detected (by their change of brilliancy). Maps of the whole sky are now made by photography and they record millions upon millions of stars. The inventory of the stellar universe will soon be completed, a magnificent gift of this century to the next.

Photography has proved to be of immense importance in the study of the Moon. A satisfactory picture of the full Moon can be made in less than a second of time which will show more than is contained in the best lunar maps that required a lifetime to construct by the old methods. The study of the solar corona would have been impossible without the photographic plate.

The mysterious world of the nebulæ, too, is depicted by means of photography with extraordinary faithfulness, the work of years of observation being compressed into hours. Up to this time little success has been attained, however, in the study of planetary features by photography, and the old methods of telescopic examination and pictorial representation by drawing are still employed. It is partly for this reason that so much remained doubtful in the accounts of the surface details of Mars, Jupiter, etc.

In the study of the physical characteristics of comets also photography has proved to be of the very first importance. Features quite impossible to see with the eye are distinctly shown on the negative plate, and in this field we are on the very verge of great discoveries. The connection of comets with meteor swarms is a fact of capital importance.

The electric telegraph has revolutionized certain parts of astronomy and geodesy. All longitudes are now fixed by "the American method" with unheard-of accuracy and rapidity, and the figure of our globe will soon be well determined. One of the

striking discoveries of the century is Dr. Chandler's detection of a minute regular change of the axis of rotation of the Earth whose effect is shown in a regular, though small, variation of the latitudes of places. This discovery is an excellent example of the thoroughness with which all astronomical work, both observation and calculation, is now performed.

At the beginning of the century Sir William Herschel was in midcareer. He discovered the planet Uranus in 1781; its two brighter satellites were discovered by him in 1787; the two innermost satellites of Saturn in 1789. The satellite of Neptune was discovered by Lassell in 1846; two more satellites to Uranus, again by Lassell, in 1851; a satellite to Saturn by Bond in 1848; two satellites to Mars by Hall in 1877; a satellite to Jupiter by Barnard in 1892; a ninth satellite to Saturn by Pickering in 1899.

Newton's discovery of universal gravitation reached no further than the outermost planet known to him, Saturn. The discovery of Uranus and Neptune extended the scope, but Herschel's detection of systems of binary stars revolving about each other according to this law made gravitation truly universal; the law was effective to the boundaries of the universe. Our knowledge of double stars has been vastly extended by the discoveries of this century. Thousands of such systems have been discovered and many orbital motions are already calculated.

To Herschel a star was a shining body like the Sun, both being of unknown constitution. The spectroscope (invented by Bunsen and Kirchhoff in 1859) brought a new engine to bear on problems until then utterly unsolvable. The spectrum of the Sun, or of a star, compared with the spectra of terrestrial substances, proves the existence in the fiery envelopes of these bodies of incandescent clouds of metallic vapors. Lead, iron, gold, copper and other metals are there present.

The nebular hypothesis of Laplace (published in 1706) had declared that the Sun and all the planets were but condensations from a single vast nebula that once filled all space. The spectroscope proves that the stars, the Sun and the Earth are made up of the same elements. If the Earth were to be raised to the temperature of the Sun it would be like it—a miniature sun. The Sun is, in fact, a star. The stars are, in general, composed of terrestrial elements. This great generalization strengthens the nebular hypothesis in its larger acceptation, but the century has brought forward many doubts as to its minor details. With the

discovery of the spectroscope the science of astronomical physics was born. The most amazing single results of spectroscopic observation is the determination of the velocity with which stars are approaching to or receding from the Earth. All stars are in motion with respect to the Earth. As they move away from or toward us the pitch of their spectral lines is altered by their velocity, precisely as the pitch of the bell of a passing locomotive engine is altered by its motion toward us or from us. We are approaching some stars; we are receding from others. The line of the motion of our whole solar system can thus be drawn in the universe, and this problem is now being worked out in all its details at several places, notably at the Lick Observatory.

In the foregoing paragraphs it has not been possible to note more than a few of the greater achievements of the astronomy of the century. Only a few of the greater men are named. A full account of the astronomical progress would require a volume, and it would include a host of honored names. In each and every department we should find Americans in the highest places. Nowhere has astronomy flourished better than upon our soil, and we may look forward to the next century with confidence.—"*Evening Star*" (*Wash.*), *Nov. 3, 1900.*

ON THE ADJUSTMENT OF THE EQUATORIAL TELESCOPE.

SECOND PART.

KURT LAVES.

FOR POPULAR ASTRONOMY.

Having derived in the first part of this paper the mathematical formulæ, upon which the final adjustment of the equatorial depends, it is left to show how the quantities $\xi, \eta, \Delta D, \Delta T, c, n, E, e$, can be determined from actual observations of the stars. Before doing this it will be necessary to indicate how an equatorial is to be put *approximately* into position without the use of the elaborate system of equations (9) and (10).

§ 6. *The approximate adjustment of the equatorial.*

This problem resolves itself into two parts:

(1) To bring the polar axis of the instrument into the plane of the meridian.

(2) To point the polar axis to the pole of the heavens, *i. e.* to give to the polar axis an elevation above the horizon, which is equal to the latitude of the place of observation.

For the first part it is necessary to show how we determine the sidereal time for any given standard time. From an accurate map we take the longitude of the place of observation from Greenwich. The sidereal time at Greenwich mean noon for every day in the year is given in the *Nautical Almanac* on page II of the monthly calendar (pages 2 to 217; the eighteen pages devoted to each month numbered by Roman numbers). This quantity changes by $3^m\ 56^s.55$ in 24^h which gives an hourly change of nearly 10^s. We compute the sidereal time for local mean noon by adding to the sidereal time for Greenwich mean noon 10^s multiplied by the longitude expressed in hours. Thus we know the sidereal time for local mean noon for every day. To transform a given standard time into local mean time we must know the difference between the standard meridian and the local meridian; if the standard meridian is east of the local, we subtract the difference in longitude from the given standard time; if it is west, we add it to the standard time. We next transform a given local mean time into sidereal time by changing the mean time interval since noon, into a sidereal time interval using for this purpose table III (pp 548-550). This value we add to the sidereal time at mean noon and obtain the sidereal time corresponding to the mean time moment [we have assumed that we had to do with a P. M. time]. But we need for our purposes also the knowledge of the mean time when the sidereal time is given. It is evident that we have then to subtract from the given sidereal time the sidereal time at mean noon. This difference, which is expressed in sidereal time, we transform into mean time by table II (pp. 545-547).

The right ascension of the star α Ursæ Minoris (North Star) is now $1^h\ 23^m$; when it is in upper culmination the sidereal time is equal to $1^h\ 23^m$. We find for a given day the corresponding mean time and turn our equatorial instrument to the star a few minutes before the culmination occurs. We keep the declination axis in a horizontal position; an assistant shifts the basis of the instrument till the star appears in the field and keeps turning it till the star is, at the computed time of culmination, well in the middle of the field. In the late fall the upper culmination of the North Star takes place conveniently in the early evening hours; in the spring the lower culmination will have to be used instead.

To give to the polar axis the proper elevation we should observe the declination of a star in both positions of the telescope, east and west of the pier. We shall then have two equations of

the character of those under (9) in the preceding article, which could be solved for ξ and ΔD. To find the value of ΔT it is necessary to have the declination axis in a horizontal position and to observe the instrumental hour angle of an equatorial star in both positions. We would then form the arithmetical mean of the two equations corresponding to those under (10) and find the index error of the hour angle circle. To effect the horizontality of the declination circle, a level attached to the declination axis seems to be necessary. But very few instruments are provided with such a level and it seems therefore impossible to obtain ΔT independent of the error of the chronometer, if this one is not known from observations with the meridian instrument. A simple but very ingenious method has been devised by Professor Schaeberle to overcome this difficulty, and since from it at the same time the value for ξ and ΔD can be conveniently determined in day time it will be best to reprint here the clear exposition of the method as given by Professor Campbell in his *Practical Astronomy* (2d ed. pp. 215-216):

"Across the object end of the telescope firmly tie a piece of "wood which projects several inches from the telescope tube on "the side opposite the pier. Pass a fine thread through a very "small hole in the projecting end and fasten it. Direct the tele- "scope to the zenith. Near the eye-end and on the same side as "the projecting arm, fasten a block of wood. To this screw a "metal plate so that it will be perpendicular to the axis of the "tube, and in which is a very small circular hole as nearly as pos- "sible (by estimation) under the hole above. Pass the thread "through it, tie a plumb-bob to the end of the thread near the "floor, and let it swing in a vessel of water. Move the telescope "by the slow-motion screws until the plumb-line passes through "the center of the lower hole. Read both verniers of the hour "and declination circles. Unclamp, hold the plumb-bob in the "hand to avoid displacing the metal plate, remove the telescope "to the other side of the pier and set it so that the plumb-line "again passes centrally through the hole. Read both circles as "before.

It is obvious that the two readings of the declination circle give rise to the following two equations (see equation 9):

$$\phi = D' + \Delta D - \xi \qquad \text{C. P.}$$
$$\phi = D'' - \Delta D - \xi \qquad \text{C. F.}$$

Indeed the declination of the zenith is the latitude of the observer, the term in e will be zero. From these observations we

obtain $\Delta D = \frac{D'' - D'}{2}$ and $\xi = \frac{D'' + D'}{2} - \phi$. (The value of ϕ can be obtained from a map with sufficient accuracy for this preliminary work). Placing the index of the declination circle on $\frac{D'' + D'}{2}$ by means of the slow-motion screw, we shift the index arm bodily by the amount $\frac{D'' - D'}{2}$ in the proper direction. We next place the index on the declination $= \phi$ and move the polar axis by means of the proper screw till the plumb-line will take its position in the middle of the circular hole. The adjustment of the polar axis being accomplished, we take the arithmetical mean of the hour circle readings. This taken with the negative sign is the value of ΔT; placing the index on the hour circle equal to the arithmetical mean, we shift the index arm till it reads $0^h\ 0^m\ 0^s$.

With the adjustment so far effected it is possible to obtain a closer determination of the error of the chronometer. It will be readily granted that the error with which the longitude can be taken from a map is large and that standard clocks which are daily regulated by means of a time signal from the Washington Observatory are not always easily reached. It will therefore be preferable to do away with this round-about method of finding the sidereal time from the mean time. The stars will furnish us the correct time. For this purpose we turn to equation (10) (Part I). The hour angle of a star is the difference between the sidereal time and the right ascension of the star. Let, at two moments of time, θ' and θ'' be the sidereal times as obtained from the chronometer, and let $\Delta\theta'$ and $\Delta\theta''$ be the corrections to be applied to θ' and θ'' respectively, to give the correct sidereal times. Assume $\theta'' - \theta'$ smaller than 10^m, then we may assume that $\Delta\theta'$ will be equal to $\Delta\theta'' = \Delta\theta$ for a fairly good watch. Select a star which culminates near to the equator and observe its transit over the vertical wire in both positions; *C. P.* when the instrumental hour angle is about 3^m east, and *C. F.* when it is about 3^m west. From the foregoing definition we have

$$\tau' = \theta' + \Delta\theta - \alpha \text{ and } \tau'' = \theta'' + \Delta\theta - \alpha.$$

With these values we find,

$\theta' + \Delta\theta - \alpha = T' + \Delta T - c \sec\delta - n \operatorname{tg}\delta + \eta\, tg\,\delta$ C. P.

$\theta'' + \Delta\theta - \alpha = T'' + \Delta T + c \sec\delta + n \operatorname{tg}\delta + \eta \operatorname{tg}\delta$ C. F.

We have neglected in both equations the flexures and have put $\sin\tau' = \sin\tau'' = 0$ and $\cos\tau' = \cos\tau'' = 0$ since the observations are made so close to the meridian.

By addition of the two equations we obtain

$$\Delta\theta - \Delta T = a - \frac{\theta' + \theta''}{2} + \frac{T' + T''}{2} + \eta \operatorname{tg} \delta$$

a is known from the *Nautical Almanac*, $\frac{\theta' + \theta''}{2}$ and $\frac{T' + T''}{2}$ are known from observation; we obtain therefore a value for $\Delta\theta - \Delta T - \eta \operatorname{tg} \delta$, and since we may safely assume that by the foregoing method ΔT is reduced to one unit of the graduation of the hour circle we shall obtain $\Delta\theta$ with an accuracy equal to that of ΔT provided we have taken a star so close to the equator that $\eta \operatorname{tg} \delta$ can be neglected.

§ 7. *The determination of* ΔD, ΔT, ξ, η, c, n, E, e *as derived from observations of stars.*

Since the equations (9) and (10) contain on the right sides terms which have either $\sin \tau$ or $\cos \tau$ as a factor, it will be advantageous to divide our work into two distinct parts. The first part will deal with the observations which are made close to the meridian, the other close to the $6^h - 18^h$ circle. Our equations (9) and (10) will be reduced in these two cases to the following:

(*a*). *Near the meridian.*

$$\theta' - a = T' + \Delta T - \Delta\theta - c \sec \delta - n \operatorname{tg} \delta \pm \eta \operatorname{tg} \delta \pm E \cos \frac{(\phi \mp \delta)}{\cos \delta} \quad \text{C. P.}$$

$$\theta'' - a = T'' + \Delta T - \Delta\theta + c \sec \delta + n \operatorname{tg} \delta \pm \eta \operatorname{tg} \delta \mp E \cos \frac{(\phi \mp \delta)}{\cos \delta} \quad \text{C. F.}$$

$$\delta = D' + \Delta D - \xi - e \sin (\phi - \delta) \quad \text{C. P.}$$

$$\delta = D'' - \Delta D - \xi - e \sin (\phi - \delta) \quad \text{C. F.}$$

The upper signs in the terms in E and η pertain to stars in upper culmination, the lower signs to stars in lower culmination.

(*b*). *Near the* $6^h - 18^h$ *circle.*

$$\theta' - a = T' + \Delta T - \Delta\theta - c \sec \delta - n \operatorname{tg} \delta \mp \xi \operatorname{tg} \delta + E \sec \phi \operatorname{tg} \delta \pm e \cos \phi \sec \delta \quad \text{C. P.}$$

$$\theta'' - a = T'' + \Delta T - \Delta\theta + c \sec \delta + n \operatorname{tg} \delta \mp \xi \operatorname{tg} \delta - E \sec \phi \operatorname{tg} \delta \pm e \cos \phi \sec \delta \quad \text{C. F.}$$

$$\delta = D' + \Delta D - \eta - e \sin \phi \cos \delta \quad \text{C. P.}$$

$$\delta = D'' - \Delta D - \eta - e \sin \phi \cos \delta \quad \text{C. F.}$$

The upper signs in the ξ and e terms belong to stars in the 6^h circle, the lower ones to those in the 18^h circle. It should be remarked that we have replaced in the trignometrical functions on the right side d by δ and f by ϕ. This is permitted, since each of these terms is multiplied by a small factor, so that the quantities thus neglected will be inappreciable. Only for the stars in the neighborhood of the pole, will it be necessary to use the rigorous formulas since for instance the term ξ tg δ can even for small values of τ become appreciable on account of the factor tg δ, which becomes 56 in the case of the star λ Ursae Minoris. To avoid unnecessary calculations it will therefore be wise to observe as close to the meridian, or $6^h - 18^h$ circle as possible. We cannot observe the same star in both positions near the $6^h - 18^h$ circle, since the pier will interfere, but we can easily apply the rule just stated even in this case. For the meridian observations in τ we should by all means observe each star in both positions, since we get a very valuable change of signs in this way for our equations. It will require therefore some skill to keep close to the meridian with both observations. But since we read but the hour circle for hour circle observations and pay no attention to the declination circle, the work is considerably reduced. The same holds true with respect to observations in declination, where the hour circle readings are omitted, but on account of the absence of magnifying factors in the equations for the declination, we may observe even at a considerable hour angle without danger.

(To be continued.)

NOTE ON THE COMPANION TO β CASSIOPEIÆ.

S. W. BURNHAM.

For Popular Astronomy.

The first measures of the small attendant to β Cassiopeiæ, discovered by Alvan G. Clark, were made by me at the Lick Observatory in 1889, and so far as I know it has not been measured by any other observer. I have re-observed it with the 40-inch of the Yerkes Observatory during the present year.

The two sets of measures are:

1889.59	189°.2	22″,63	3*n*
1900.70	204 .2	22 .66	2*n*

The large motion in position-angle corresponds with practical accuracy to the recognized proper motion of the bright star. This annual movement according to Auwers is 0″.550 in the direction of 110°.2. Taking this value and the position of *B* from the first set of measures as given above, the companion if fixed in space should be at the date of the last measures, 204°.8; 22″.28. This is practically identical with the observed place, and therefore the companion is not connected with the principal star. The minimum distance of 22″.4 occurred in 1897.

THE ALLEGHENY OBSERVATORY.*

The story of the old Allegheny Observatory is replete with interest not only to the astronomer, but to the good people of Pittsburg and Allegheny, for are we not proud of its history, proud of its achievement in the domain of science, proud of the men who have done so much to advance our knowledge of the beautiful science of astronomy, for discoveries of momentous interest in solar, stellar and planetary physics have been made within the walls of the dear old building on Observatory Hill, and today the discoveries made there give us a standing in the scientific world second to none.

Have we not also a pardonable pride in that noble corps of men who a little more than forty years since planned and builded the old Observatory; builded better than they knew for forty years ago little was known of the new astronomy in the field of which so much has been sown and reaped in the old institution.

On the evening of February 15, 1859, three citizens of this city and Pittsburg met at the office of Professor Bradley to consider the purchase of a telescope, "the magnifying power of which would bring the heavenly bodies near enough to be viewed with greater interest and satisfaction." These three citizens were Professor Lewis Bradley, Josiah King and Harvey Childs. After some conversation upon the subject it was decided to request other gentlemen to meet with them. The next meeting was held on the evening of Washington's birthday, February 22, 1859. At this meeting, "after further conversation, in which it was proposed to place the telescope upon a house-top in the central part

* Address of J. A. Brashear at the laying of the corner stone of the new Allegheny Observatory which took place at Riverview Park, Allegheny, Pa., October 20, 1900. The address was was printed in the *Pittsburg Press*, October 21.

of Allegheny." So far as can be learned the house selected was on the southeast corner of Parkway (then called Water Street, as it was nearest the canal) and Federal street. However, at a subsequent meeting it was decided to abandon the idea of placing it upon a house-top in the center of a city and a committee was appointed to select a more suitable site. Three sites were proposed by this committee—one on Seminary Hill, one on Quarry Hill, and a site on the west end of Seminary Hill, owned by Judge Irwin. At this time and for long afterward the association was known as the "Allegheny Telescope Association," and it is a matter of great interest to us to know of the men who were the prime movers in this pioneer astronomical association, for at that time in our history there were very few astronomical observatories of any note in the United States. I find on this roll of honor the names of Hon. Thomas M. Howe, Professor Lewis Bradley, R. S. Hays, Henry Irwin, William J. Bissel, Felix R. Brunot, John A. Wilson, James Park, Jr., Josiah King, C. G. Hussey, Edward Rahm, James Marshall, John Dean, David Campbell, William Bagaley, G. W. Cass, H. Hepburn, Henry Bollman, William Thaw, John S. Shoenberger, David McCandless, General Robinson, Christian Yeager, Mr. O'Hara, Washington McClintock, James M. Cooper, Robert Dalzell, William Morrison, Thomas Bakewell, Samuel Gormley and R. B. Sterling.

So far as I can learn all of these grand men, except C. Yeager, have passed away from Earth, but they have left an honored name, names to grace the roll of honor of any community. Many other citizens joined the association shortly after these names were recorded in the minute book, which names will be recorded at the end of this paper.

The committee on site had some negotiations with the city with reference to a location on Seminary Hill, a lease of which was offered to the association for an annual rental of sixty dollars per year, but about this time Mr. Ferguson and Mr. McClintock offered free of cost a large part of the plot of ground on which the Observatory now stands, and an additional piece was purchased from Mr. Ashworth, making in all a tract of over ten acres, on what was then perhaps as fine a location for an Observatory as could be found near the city, as the prevailing winds carried the smoke away from it, thus insuring good observations in its earlier history.

So successful was the association in raising funds for the proposed Observatory that it was decided to purchase a 13-inch telescope instead of an 8-inch, as originally proposed, and on mo-

tion of Mr. William Thaw it was decided to instruct a committee to make arrangements for the purchase of an instrument from Mr. Fitz, of New York, who had only a short time before completed a similar instrument for the Dudley Observatory at Albany, New York.

This committee, consisting of Mr. Josiah King, Hon. Thos. M. Howe and Dr. C. G. Hussey, requested Prof. Bradley to go to New York and make arrangements for the telescope of 13 inches aperture to be mounted equatorially and placed in the Observatory when completed. Professor Bradley's report was of such a satisfactory character that the proposal of Mr. Fitz, made on the 17th of January, 1860, was accepted at the meeting of the board held January 31.

The complete organization of the association did not take place until May 15, 1860, when the constitution and by-laws were reported and adopted and a board of directors elected. The members constituting the board were: Hon. Thomas M. Howe, Dr. C. G. Hussey, Mr. William Thaw, Mr. Josiah King and Mr. John H. Shoenberger.

Dr. C. G. Hussey was elected president of the board and Mr. James Park, Jr., secretary.

The act of incorporation by the legislature of Pennsylvania was approved by Governor Packer on the 22d of March, 1860.

At this epoch in the history of the Observatory there is some discrepancy in the dates, as the architect's plans were accepted and approved about the 8th of May, just a week before the election of the board of directors. Messrs. Barr & Moser were the architects.

The contract for the building was awarded to several parties, Mr. J. S. Knox building the stone work and Messrs. Smith & Bungy the carpenter work.

Mr. Fitz' work on the great telescope, its completion and the reports of the tests by Dr. Lewis Rutherford and Dr. Brunnow make up a most interesting part of the history during this period of the development of the Observatory and its equipment, all of which is recorded in the minute book of the association. Suffice it to say that the Observatory was completed and the telescope erected between the first of November, 1860, and the end of January, 1861.

Professor Bradley delivered an address before the board of trustees and their friends when they took possession of the building and instruments, but for some unknown reason this address has disappeared from the book of records of the Observatory.

On Tuesday evening, November 17, 1863, Professor Philotus Dean was elected Director of the Observatory for one year. The records do not show any important observations or discoveries made up to this time, indeed it is presumed that the telescope was used almost entirely for observations of the Moon and planets by the members of the association.

The first director of the Observatory served without any salary, save that he was furnished with a dwelling house free of rent.

On the 10th of May, 1867, a meeting was held of the stockholders of the Allegheny Astronomical association, as it is now called, to consider its transfer to the trustees of the Western University of Pennsylvania. The association had incurred an indebtedness of about $12,000 and they recognized that to carry it on in the interests of education and the advancement of science a fund must be raised to pay the debt, and also raise a fund to endow a chair of astronomy in the university. It was therefore proposed to raise the sum of $30,000 by which this desirable end should be attained. The future usefulness of the Observatory seemed to be fully recognized by the board at that time, as the minutes of this date are filled with expressions of hope and prophecy regarding both the University and the Observatory.

A large majority of stock holders and contributors voted to convey their interests in the Observatory to the University, with the proviso that they were to be credited with the amount they had subscribed, and provided further that they should have the privileges formerly accorded them of making occasional use of the instruments, and provided still further that an endowment fund be raised and the property forever be held for Observatory purposes. The Astronomical Association through its officers conveyed the Observatory to the Western University on the first day of July, 1867. The records of this transfer cover many pages of the minute books of the Western University, and bear testimony to the care with which the transfer was made.

On the 8th of August, 1867, the names of Professor S. P. Langley and Professor James Thompson were placed before the board of trustees soliciting an appointment to the chair of Astronomy and Physics. Professor Langley was unanimously elected to the chair.

At this meeting it was resolved to equip the Observatory with a transit instrument, chronograph, clocks, etc. The duties of the Professor of Astronomy were also decided upon, in which it was to teach the classes in astronomy and physics in the university, duties from which he was afterwards entirely released.

At a meeting held June 8, 1869, it was decided to change the name of the Allegheny Observatory to the "Observatory of the Western University of Pennsylvania," but at the meeting of the board on the 4th of October of the same year the motion to change the name was rescinded, and the old name retained.

Subscriptions to the endowment fund and paying off the debt amounted at this period to the sum of $15,000, subscribed by Dr. Hussey, Hon. Thomas M. Howe, Mr. William Thaw, Thomas A. Clark, Thomas Fawcett, Christopher Zug, Chas. Knap, James B. Lyon, Dr. Hostetter, Mr. Smith and General Cass. As this fund covered the indebtedness of the Astronomical Association, leaving a balance of $3,000 toward the endowment fund, thus requiring $17,000 to complete the endowment of $20,000. This amount, so far as I have been able to find out, was contributed by Mr. Thaw, who a few years afterwards also contributed $100,000 to the University fund.

It was stipulated by Mr. Thaw that the director of the Observatory should be free from teaching in the University, except to deliver lectures at his convenience and thus be free to carry on original research.

From this time onward the institution took its place among the working observatories of the world. It would be impossible within the limits of this paper to tell you more than a moiety of the splendid observations and discoveries made by Professor Langley and his able assistants. The long series of solar observations, for which this region is so well suited, gave to the world new views of the Sun and its surroundings, and the series of magnificent drawings of sun spots made by Professors Langley, Frost, Keeler and Mr. Very are now considered classic and invaluable in our studies of solar phenomena.

In his studies of solar physics Professor Langley was impressed with the idea that much of the radiant energy coming from the Sun was not recognized with the instruments then in use, and after a long series of experiments he discovered that marvelously delicate thermometer which he called the bolometer.

With the instrument a series of studies were commenced upon the Sun, Moon and stars, which brought to light some of the most important facts in the whole realm of astronomical physics. Rigorous experiments and many critical researches were made in what may be called the hitherto unknown region of solar radiation. This work covered years of earnest, patient labor and tens of thousands of observations, and now we know, through the long continued study of these devoted men that we have in the

dark rays that come from our great luminary that which is the source of all life upon our planet. I cannot dwell upon this topic, charming as it is to the student of astronomical physics. Suffice it to say that so valuable have been these discoveries that they have formed an epoch in astronomical science. Professor Langley made many more important studies and discoveries, and he became so well known in the scientific world that he was honored as few men were in his day.

Not the least important work he did at the Observatory was the introduction and development of the time service, which has been kept up without a break since it was started.

In all Professor Langley's investigations he was always assisted by that noble friend of the Observatory, through whose liberality alone he was able to carry out many of his most valuable studies. The expedition to Mount Whitney was paid for entirely by funds furnished by Mr. Thaw, and all his studies in the selective absorption of the Earth's atmosphere were carried on by means furnished from the same source. Professor Langley became greatly interested in aerodomics, or the science of aerial navigation. Upon this he made many valuable experiments from the purely scientific side. Mr. Thaw paid all the expenses of this research up to the time Professor Langley left the Observatory. The experiments are still in progress at the Smithsonian institution.

In 1890 Professor Langley was called to the highest position of any scientific institution in the land, namely the Smithsonian institution in Washington, D. C., to fill a chair that had been occupied by Henry and Baird, where, amidst his many duties, he still finds the time to carry on his bolometric and aerodromic researches. Professor Langley contributed 54 papers to scientific journals during his directorate of the Observatory.

Professors Frost, Hall, Very and Keeler had been associated with Professor Langley during his stay at the Observatory, all of whom have made for themselves an honored record. Professor Frost now occupies the position of professor of physics in the Western University and Professor Very accepted a position at Ladd Observatory of Brown University.

Professor Keeler, after spending a year studying with Helmholtz and Quinke in Germany, returned to the Observatory, where he further assisted Professor Langley in his researches of the selective absorption of solar energy and other problems of scientific value.

In 1886 Professor Keeler was called to the Lick Observatory, where he had charge of the erection of the instruments and installed all the apparatus for the time service, and was the only astronomer on the mountain for many months. After Professor Holden took charge of the Lick Observatory Professor Keeler was appointed astronomer. Here he soon developed the astronomical spectroscope to a high degree of perfection and made a series of observations on the motion of the nebulæ in the line of sight, which at once brought his work the highest recognition throughout the scientific world. His magnificent drawings of the planets Jupiter, Saturn and Mars, made by the aid of the great 36-inch telescope, have never been equalled. Many other studies of importance were conducted at the Observatory, which at once placed Professor Keeler as one of the most earnest and successful observers in the realm of the new astronomy.

In May, 1891, Professor Keeler was unanimously elected to the directorship of the Allegheny Observatory, a position he at once accepted. When Professor Keeler came to Allegheny he found the Observatory poorly equipped for the line of investigation he desired to pursue as a continuation of his work at Lick Observatory, but friends of the institution and of Professor Keeler soon furnished the means. Mrs. William Thaw contributed the money to construct a spectroscope of the highest type, which was designed by Professor Keeler. Mr. William Thaw, Jr., supplied the means for a new driving clock and the remounting of the 13-inch equatorial, while the Junta club of Pittsburg generously donated a sum sufficient to place a modern shutter on the dome. Thus equipped, Professor Keeler commenced a series of researches by which, in the years he was with us, some of the most brilliant discoveries ever made in astronomical science were added to those he had already given to the world.

Of the sixty-two papers he contributed to various scientific journals during his directorate perhaps the most important ones are those which we have numbered 120 and 121 in the transactions of the Observatory. No. 120 refers to his spectroscopic study of the constitution of Saturn's rings; No. 121 a paper on a spectroscopic proof of the meteoric constitution of Saturn's ring. Had he made no other discovery than this solution of the character of Saturn's rings, his name would forever be remembered in the annals of scientific discovery, for the mathematicians, physicists and astronomers of centuries had labored in vain to solve the problem, which, with his keen intellect, his methods of precision, his marvellous ability to make his instrumental epuip-

ment do his bidding enabling him to solve the mystery and establish the splendid theory of Doppler on a still more secure foundation.

It would be impossible, in the limits of this paper, to tell you of the splendid achievements in the domain of astrophysics of our departed friend, for since this new temple of the skies began to rise from its foundation his spirit has taken its flight to dwell among the stars he loved so fondly. Socially, Mr. Keeler was a most charming man, and as a scientific investigator he was of the highest type, ever ready, ever willing to help the earnest student over the rough ways that here and there lay before him. Thousands of our people have enjoyed his Thursday night receptions at the Observatory, and he was one of the first to suggest that if we should have a new Observatory, one department should be erected that should be forever free to the people, so that they too might enjoy the beauties of the skies.

Professor Keeler was elected director of the Lick Observatory in the spring of 1898. He did not wish to leave us: social and scientific associations, ties of friendship bound him to us closely and had we succeeded in raising a fund large enough to build a new Observatory on this beautiful spot, which had been secured long before he left us, I do not think that even the great attractions of that ideal Observatory on the summit of Mount Hamilton would have been sufficient to take him from us, but the breaking out of the Spanish-American war and the excitement associated with it prevented for the time being the successful issue of the important enterprise. Notwithstanding all this, Professor Keeler hesitated as long as he could, with courtesy to the Lick trustees, and only accepted the position when the time limit was reached. The two years since his acceptance of the directorate of the great mountain Observatory were replete with success, and we lovingly place under this corner stone a record of the last and one of the most important discoveries he had yet made, indeed in a recent letter to me he modestly mentioned it as the greatest discovery of his life, namely that the normal condition of the greater number of nebulæ are spirals.

But he has gone from among us leaving a loving companion and two bright children to honor his memory.

Professor Frank Very remained at the Observatory until his work undertaken for the United States weather bureau on atmospheric radiation was practically completed. This work has just been issued from the government press, and in Professor Moore's transmittal of the work to the secretary of agriculture,

he acknowledged it to be a research of great importance in the absorption and radiation of heat in the Earth's atmosphere.

Professor Henry Harrar was a faithful assistant to Professor Keeler, having charge of the time service and other duties in connection with Professor Keeler's research work.

After an interim of about eighteen months our present director, Professor F. L. Wadsworth, was unanimously elected to fill the place made vacant by the resignation of Professor Keeler.

Before Professor Keeler left us he had made a carefully prepared plan for a new Observatory. Professor Wadsworth at once took a deep interest in working out the details of the proposed new building and after spending the best part of a year on the plans, he has given to us to the most minute detail a building in which the science of astrophysics can be studied as never before, a building large as it is, has every nook and corner suited to carrying out some problem in the new astronomy of which there are vast fields yet unexplored, and in which our new director, let us hope, may reap a harvest of discovery yet undreamed of. Professor Wadsworth comes to us as Professor Keeler's first choice. He has already made many important researches in the realms of astrophysics. He has labored day and night for the success of the new Observatory, and we only trust that with his indomitable will and energy he will not pass the elastic limit and break down ere his work is finished.

Our architect, Mr. T. E. Billquist, has put many hours of faithful work into the development of the exterior beauty and completeness of the building throughout, and we trust when it is finished it will be an honor to him and his craft, and, may I add, that if the remainder of the Observatory is constructed by the contractors with the same fidelity and good workmanship that has characterized the work already done, we shall have a building that will stand the storms for centuries.

The Observatory committee of the board of trustees of the university wish also to speak of the generous manner in which the officers of the city government have treated us. Mr. McAfee, Mr. Fulton and Mr. Brown have done everything in their power to facilitate our work. A six-inch water-main has been laid to the very door of the Observatory, and Mr. Fulton has been untiring in his efforts to help us on to ultimate success.

Our site, so kindly given us by those of our citizens who purchased the park for the city and deeded it to us forever for the Observatory, is one almost unsurpassed for the beauty of its scenery, and as the prevailing winds bring us but little smoke, we

think we have reason to be hopeful for a continuance of the splendid work of the old institution. Our work will proceed as rapidly as material can be secured, and by this time a year hence we hope to see the completion of the building, although we can scarcely expect to have the instrumental equipment finished by that time, but this instrumental equipment has been thoroughly worked out by our director with especial reference to a continuance of studies of yet unsolved problems in the domain of astronomy and astronomical physics.

One department of the Observatory we propose shall be open day and night to the students in the high schools and higher grades of the common schools in both cities, and to every citizen who wishes to enjoy the fragrance of the "flowers of the sky." When all is complete,

> "Then will holy science, putting off
> Earth's dusty sandals from her radiant feet,
> Survey God's beauteous firmament unrolled
> Like a book new writ in golden words,
> And turn the azure scroll with reverent hand
> And read to man the wonders God hath wrought."

TOTAL ECLIPSE OF THE SUN MAY 28, 1900.*

CHARLES P. HOWARD.

Four days before the eclipse, I joined the Trinity College party at Winton and set up my instruments beside theirs, on the edge of a bluff 40 feet high, on the southwest bank of the Chowan river, here 750 feet wide. This location was a fine one for observing every aspect of the eclipse, for it gave a perfectly clear view of the eastern sky, across a wide expanse of water.

My instruments consisted of a 4-inch photographic telescope, to the upper end of which was attached a 2-inch visual telescope. The photographic object-glass had a focal length of 58 inches, and gave an image of the Moon 0.52 inches in diameter on a 4 by 5-inch plate. The tube was of wood 6 inches square and was, of course, nearly 5 feet long.

The visual telescope had an object-glass of 1.97 inches clear aperture and 22 inches focal length, and the Miller solid achro-

* A short account with rough illustration was published in the Hartford Courant of June 2d, and also in the Trinity College Bulletin No. 2, for July, 1900. Observations were made at Winton, North Carolina.

matic eyepiece used, gave a field of view 2° 10′ in diameter, and a magnifying power of 18. The field of view was therefore equal to four diameters of the Moon.

Both telescopes were made to follow the motion of the Sun, by a simple contrivance. The upper end of the wooden tube rested on a polar axis, while its lower end heavily weighted, rested on a 4-inch piston traversing a cylinder filled with oil. The cylinder was thickly jacketed to prevent external changes of temperature from affecting the viscosity of the oil. The speed with which the piston descended through the oil, was regulated by a small valve. This method of supporting the tube at both ends was very satisfactory, giving great steadiness and freedom from vibration, but its rate of motion was not quite perfect.

All was mounted on a heavy tripod 7 feet high, bolted to stakes driven firmly into the ground and having a plumb-bob swinging seconds suspended from its apex.

Previous to the eclipse the following program for the 99 seconds of totality was planned aud rehearsed, until its performance became automatic:

1st. 8 seconds for a general naked-eye view of the spectacular aspects of the eclipse.

2nd. 74 seconds for taking six photographs of the corona, with exposures varying from ¼ second on slow plates to 20 seconds on rapid plates, and during the 20 seconds exposure, to have another and longer naked-eye view of the eclipse.

3d. 18 seconds for a view of the corona through the 2-inch telescope.

Unfortunately this program was exactly carried out, for although five of the photographs proved perfect, it was a great mistake to give so much time to photography, and so little to the view through the wide field telescope.

During totality, the atmospheric conditions were phenomenally perfect.

1st. There was a dead calm accompanied by an impressive stillness, that many remarked could actually be felt.

2nd. The air was remarkably clear and transparent. There was not a single cloud, nor a trace of haze, smoke or whitish film in the sky.

3d. Best of all, the telescopic seeing was perfect. Through the telescope not a single tremor of the atmosphere was noticed.

During the partial phase, I had carefully avoided looking at the Sun or at any bright object, in order that during totality my retina should be as sensitive as possible to faint objects. Near

second contact I kept my eyes fixed upon the ground and saw the feeble sunlight die rapidly away, with a sort of trembling motion, until it disappeared entirely and it was evident that totality had commenced. I then looked up at the eclipse and saw the corona different from what was expected: There was no very bright inner corona, but only a pale greenish-yellow glow uniformly surrounding the Moon. This halo was brightest at at the limb, and faded rapidly away until lost to sight at a distance of about one-quarter of the Moon's diameter.

The outer corona though much paler, was very distinct, and instead of being hazy and of indefinite outline, had as hard and definite boundaries, and appeared of almost as uniform a tint as if cut from cardboard. It gave the effect of two wings, extending east and west from behind the Moon, each to a distance of about two and one-half diameters, and had a lively or active look that gave to the Sun the appearance of flying.

The naked-eye view of the eclipse was very impressive, particularly the unnatural blue-black color of the sky, and the much blacker disk of the Moon, with the coronal wings extending from behind it. The general darkness was much greater than that at full Moon, for it was difficult to see the swinging plumb-bob, but the general illumination of the sky was much greater, for only one fixed star could be seen by any of our party. The light on the landscape came from the widely diffused light in the sky from beyond the Moon and from a faint brownish illumination of the sky near the horizon, and but little came from the corona itself.

The view through the telescope, however, was far grander than the naked-eye view and most awe-inspiring. Around the Sun was an appearance that almost made one exclaim, "the Sun is an enormous magnet, alive and hard at work."

I made an attempt to represent the general effect of this first view, and although doing so with some degree of accuracy, it but faintly indicates the beauty, grandeur and solemnity of the great action going on all around the Sun.

At the first look it was perfectly obvious that the bright ball of the Sun was wholly hidden behind the black disk of the Moon. Emanating from it in all directions, but not all radially, were an almost infinite number of pink and greenish-yellow forms of various degrees of luminosity, that as a whole formed an oblate spheroid, enveloping the Sun.

The apparent elliptical outline of the spheroid extended 2° in the direction of the Sun's equator, and 7/8° in the direction of the

Sun's poles. Its whole volume was full of these strange forms, most of them seen in perspective, that made it seem to round up toward the eye, in a very striking manner.

With the exception of eight self-luminous "stalks" rising from each polar region, these forms appeared to consist of three distinct kinds:

1st. Long quiescent pink streamers rising from both polar regions and arching away to right and left, in curves that at the moment gave the impression of being magnetic.

2nd. Short quiescent pink stems with enlarged tops, standing out radially from the southwest limb of the Sun like a fungus growth.

3d. Projected greenish-yellow wings, rays, fountains and wisps, thrown out of the Sun in every direction, and at all sorts of angles so as often to cross each other, all showing decided perspective and making as a whole an intricate and involved mass. Some of them were brighter and some were darker, than the mass of similar forms composing the background against which they were seen. Some and perhaps all of the dark ones were not rifts between the bright ones, but were actually composed of darker material as proved by the appearance and arrangement of the minute filaments of which they were composed. Although the color of most of them, when examined separately appeared greenish-yellow, some near the plane of the equator seemed pink, and the general effect of them all was pinkish.

Of course it was impossible to tell whether the filaments of these jets were really in rapid motion or were so in appearance only, for not the slightest motion was noticed; nor could have been detected during the almost instantaneous glimpse of them obtained, had their velocity been even at housand times greater than that of a common ball.

All three kinds of forms had the remarkable characteristics:

1st. They had a peculiar crispness of appearance unlike any other object with which I am acquainted.

2nd. They consisted of an excessively attenuated kind of matter; as was proved both by their reflecting so little light, and by their being apparently entirely uninfluenced by the attraction of gravitation.

3rd. They were all practically perfectly transparent, so that any number of them could be seen through each other.

4th. When looked at attentively, only one set of forms could be seen at once; all the others, even those situated in the same line of sight, becoming invisible. This phenomenon was particu-

larly noticed at the south pole, where three or four sets of forms appeared superposed—viz., the white stalks, long pink streamers, dark jet and explosive rays. When either of them, it did not matter which, was looked at attentively, that one could be seen with perfect distinctness, but the others, for the time being, were invisible.

In the first general view of the corona, the most conspicuous of the projected forms were four broad wings, that rose from the Sun at about latitude 65° and arched away to right and left in beautiful curves; as if the matter composing them, was acted on by an intense force that repelled it from the poles and compressed it toward the plane of the equator. Their appearance was not that of a thin sheet, but they seemed to round up towards the eye as if having considerable volume.

Only two other of these projected forms, happen to catch my attention, although they probably were not more conspicuous than many others. The first was a broad smooth bright wing, decidedly pinkish in color, extending from the south equatorial region towards the east, but cut off from the Sun by a darker wing that seemed to pass diagonally across it. The second was a decidedly dark, fountain shaped jet, of a clear greenish-brown or gold color, projected somewhat diagonally from a little west of the south pole. It had a rather broad base and ran up to a sharp point, and appeared somewhat more than one-third of the Sun's diameter high. It was full of a sort of ruffled up detail, made up of minute short filaments seen with the most perfect distinctness. It curved slightly away from the pole and showed strong indications of perspective as if inclined towards the eye.

While examining this dark jet I saw many other nearly straight bright greenish-yellow rays composed of the same kind of short filaments, apparently thrown off by the Sun radially to beyond the limits of the spheroid.

This filamentous structure was seen with wonderful distinctness, although it was so fine as to be about at the limit of vision. The filaments all seemed to be of about the same size, 600 miles in diameter by 800 miles long. They ranged about longitudinally along the jets, not smoothly as if combed, but bunched together more in some places than in others. They were not straight and geometrical but were bent slightly in groups.

The only surface I have seen since the eclipse giving a somewhat similar effect, is that of a field of coarse grass gone to seed, with each high stem ending in a cylindrical tuft. When these tufts stand so high and numerous that no blades of grass show among them, the field has a certain resemblance to this filamentous structure.

(To be continued.)

SPECTROSCOPIC NOTES.

The complete account of Dr. Wilsing's important work on the spectrum of Nova Aurigæ constitutes No. 40 of the Potsdam Observatory Publications. The characteristic double lines of the Novae, each having a bright and a dark component, are described; and against the prevailing explanation, that this appearance results from two unlike stellar components moving with great relative velocity, strong objections are urged. Dr. Wilsing's experiments are described in which he has succeeded in producing artificially lines practically identical in structure with those of the Novae.

Professor W. H. Pickering, in his study of Swift's comet, 1892 I, (Harvard Annals, Vol. 33 Pt. 2; *Nature*, Sept. 20) finds that the spectrum photographs show an intense and very narrow line about λ 3890, with no indication of hydrogen lines.

Professor Campbell contributes to the *Bulletin of the Astronomical Society of the Pacific*, No. 75, an account of his expedition to Georgia to observe the eclipse of May 28. His spectroscopic observations indicate that the matter radiating the green light is conspicuously heaped up in the sunspot zones; that the position of the green corona line is at λ 5303; and that the spectrum of the inner corona is free from dark lines.

The report of Her Majesty's Astronomer at the Cape of Good Hope for the year 1899 states that Mr. Lunt has charge of the McClean telescope and the work of the Astrophysical department, and that Mr. Bergh has assisted at the McClean telescope. The report refers briefly to the return of the photographic objective for correction of faults of color-correction, and to the papers communicated to the Royal Society on the occurrence of lines of oxygen and silicon in certain star spectra.

Mr. Aitken (*Bulletin of the Astronomical Society of the Pacific*, No. 75), examining Capella with the great Lick refractor on occasions of greatest separation of the spectroscopic components and under favorable circumstances, has been unable to detect the least evidence of visual duplicity.

It would seem, then, that κ Pegasi, after this second and very surprising attempt to displace it, is to remain for the present the shortest known visual binary. Professor Campbell (*Bulletin Astron. Soc. Pacific*, No. 75) finds that one of its components is a spectroscopic binary. The components are so close that he has not been able to determine definitely which of them is the spectroscopic binary, though it is probably the one which is stronger in the blue end of the spectrum. The period of the bright star about its invisible companion is about 6 days. There are certain changes in the character of the spectrum not yet determined.

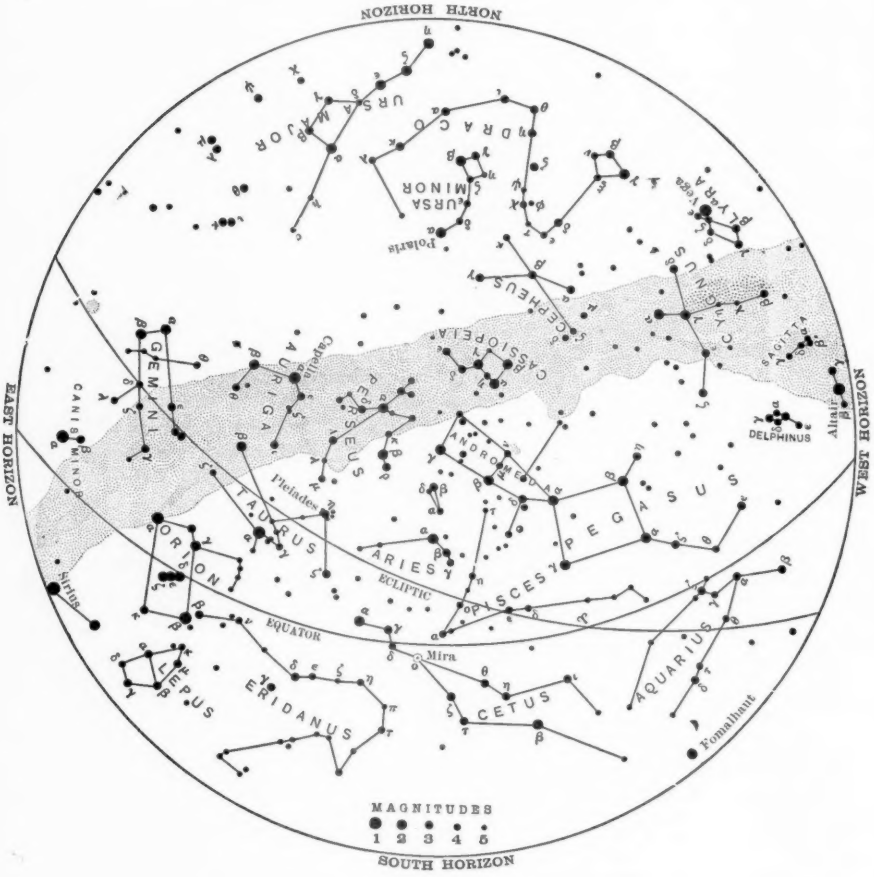
PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be at greatest elongation west from the Sun 20° 50′, Dec. 7, and so will be visible as morning star during the first two weeks of the month. One must look for it toward the southeast, near the horizon, from an hour to a

half hour before sunrise. Mercury will be in conjunction with the Moon Dec. 20 at 6 A. M., with Uranus Dec. 22 at 9 A. M. and with Jupiter Dec. 30 at 10 A. M.

Venus rises about 4 A. M. and is near the meridian between 9 and 10 o'clock in the forenoon, when the planet may be seen without the aid of a telescope although her brightness is only about one-third of that in August last. Venus and the Moon will be in conjunction Dec. 19 at 1 A. M.



THE CONSTELLATIONS AT 9 P. M., DECEMBER 1, 1900.

Mars must have been recognized by all who watched for the Leonid meteors, as the bright ruddy star which deformed the handle of the "Sickle" in Leo. The planet is a little brighter than Regulus and therefore of the first magnitude or brighter. The diameter of its disk is a little over 8″ and will increase during

December to nearly 11″. Mars will be in conjunction with the Moon Dec. 12 and with the star *l* Leonis Dec. 16 at 8 A. M., at which latter time the star will be only 6′ north of the planet.

Jupiter, *Saturn* and *Uranus* are behind the Sun, superior conjunction occurring for Uranus on Dec. 5, for Jupiter Dec. 14 and for Saturn Dec. 29.

Neptune comes to opposition Dec. 19 and so is in best position for observation. Its place Dec. 15 is R. A. $5^h\ 51^m\ 12^s$; Decl. $+22°\ 11'$. Its motion during the month is westward, amounting to a little less than one degree.

The Moon.

	Phases.	Rises. (Central Standard Time at Northfield; Local Time 13m less).	Sets.
		h m	h m
Dec. 6	Full Moon	5 02 P. M.	8 40 A. M.
13	Last Quarter	11 28 "	11 55 "
21	New Moon	7 21 A. M.	4 37 P. M.
28	First Quarter	11 27 "	12 43 A. M.

Occultations Visible at Washington.

Date. 1900.	Star's Name.	Magnitude.	IMMERSION. Washington M. T.	IMMERSION. Angle f'm N pt.	EMERSION. Washington M. T.	EMERSION. Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
Dec. 3	π Arietis	5.7	16 36	88	17 25	259	0 49
4	13 Tauri	5.7	13 01	122	13 58	227	0 57
4	14 Tauri	6.3	13 54	141	14 33	211	0 39
6	ζ Tauri	3.3	8 05	51	9 00	299	0 55
9	A^1 Cancri	6.0	17 56	87	18 59	325	1 30
10	ω Leonis	5.9	14 42	123	16 10	296	1 28
12	55 Leonis	6.2	11 37	175	12 04	228	0 27
12	p^2 Leonis	5.4	16 33	110	18 00	316	1 27
17	10 Libræ	6.5	14 30	78	15 20	319	0 49
27	κ Piscium	4.7	7 04	74	8 14	229	1 10
27	9 Piscium	6.6	7 19	115	8 01	189	0 42

COMET AND ASTEROID NOTES.

Comet 1894 IV (E. Swift).—The perihelion passage of this comet does not occur until Feb. 13 next but it will then be involved in the rays of the Sun. A finding ephemeris was computed by Mr. F. H. Seares beginning with July 23 and ending with Dec. 30. The comet has not yet been found and there is but little hope that it may be picked up during this month, the circumstances are so unfavorable. The finding ephemeris for December is as follows:

Berlin Midnight.	R. A.	Decl.	log Δ	Aber.	Light.
	h m s	° ′		m s	
Dec. 2	19 26 54	−24 30.5	0.3900	20 25	0.11
6	37 43	24 04.1	3916	29	
10	48 38	23 34.4	3932	34	
14	19 59 39	23 01.7	3948	38	0.12
18	20 10 44	22 25.9	3965	42	
22	21 54	21 46.9	3981	47	
26	33 07	21 04.5	3996	52	
30	20 44 24	−20 19.1	0.4011	20 57	0.12

WEST HORIZON

Ephemeris of Brorsen's Comet.

1900.	R. A.	Decl.	log r	log Δ	$1:r^2\Delta^2$
	h m	° ′			
Nov. 23	22 17.8	−53 54	0.0691	9.9500	0.9
25	16.6	53 17			
27	15.5	52 39	0.0487	9.9373	
29	14.6	51 59			
Dec. 1	13.8	51 18	0.0271	9.9227	1.3
3	13.1	50 35			
5	12.5	49 50	0.0044	9.9059	
7	11.9	49 3			
9	11.3	48 14	9.9806	9.8866	1.8
11	10.6	47 23			
13	9.8	46 29	9.9557	9.8645	
15	8.8	45 32			
17	7.7	44 32	9.9298	9.8392	2.9
19	6.3	43 28			
21	4.4	42 20	9.9031	9.8104	
23	22 2.1	41 6			
25	21 59.2	39 46	9.8761	9.7779	4.9
27	55.6	38 19			
29	51.2	36 45	9.8494	9.7419	
31	45.8	35 0			
Jan. 2	39.4	33 4	9.8241	9.7037	8.8
4	31.7	30 54			
6	22.7	28 30	9.8016	9.6659	
8	12.4	25 49			
10	21 8.9	22 54	9.7835	9.6338	14.6
12	20 48.3	19 44			
14	35.0	16 24	9.7717	9.6146	
16	21.3	12 59			
18	20 7.6	9 37	9.7676	9.6146	17.2
20	19 54.4	6 26			
22	19 42.1	− 3 28	9.7717	9.6340	

Ephemeris of Comet 1900 *b*.

1900.	R. A.	Decl.	log r	log Δ
	h m s	° ′ ″		
Dec. 1	16 3 9.47	+69 38 51.6	0.32810	0.26920
2	4 53.44	69 52 27.4	33055	27087
3	6 38.19	70 6 23.5	33299	27240
4	8 13.71	70 20 39.5	33541	27400
5	10 10.09	70 35 14.8	33783	27560
6	11 57.38	70 50 9.5	34023	27719
7	13 45.61	71 5 23.1	34261	27877
8	15 34.85	71 20 55.7	34498	28036
9	17 25.14	71 36 46.6	34733	28194
19	19 16.52	71 52 55.8	34967	28352
11	21 9.02	72 9 23.0	35200	28510
12	23 2.89	72 26 8.1	35431	28669
13	24 57.97	72 43 10.5	35661	28828
14	26 54.43	73 0 30.1	35890	28987
15	28 52.31	73 18 6.5	36117	29147
16	30 51.71	73 35 59.5	36343	29307
17	32 52.71	73 54 8.7	36568	29468
18	34 55.40	74 12 33.7	36792	29630
19	36 59.91	74 31 14.3	37014	29792
20	39 6.34	74 50 9.9	37235	29956
21	41 14.81	75 9 20.3	37455	30120
22	43 25.44	75 28 45.0	37673	30285
23	45 38.42	75 48 23.5	37890	30452
24	47 53.88	76 8 15.4	38106	30620
25	16 50 12.02	+76 28 20.5	0.38321	0.30788

1900.	R. A.			Decl.			log *r*.	log. Δ
	h	m	s	°	′	″		
26	16	52	33.03	+76	48	38.2	0.38535	0.30958
27		54	57.19	77	9	7.8	38747	31130
28		57	24.73	77	29	48.9	38958	31303
29	16	59	56.03	77	50	40.9	39168	31477
30	17	2	31.39	78	11	43.4	39377	31653
31		5	11.21	78	32	55.7	39585	31831
Jan. 1		7	55.94	78	54	17.4	39791	32011
2		10	46.11	79	15	47.9	39997	32191
3		13	42.31	79	37	26.6	40201	32374
4		16	45.23	79	59	12.9	40405	32558
5		19	55.66	80	21	6.2	40607	32744
6	17	23	14.51	+80	43	6.0	0.40808	0.32933

Ephemeris of Planetoid (306) Unitas.

1900	R. A.			Decl.			log. *r*	log Δ	Aber.
	h	m	s	°	′	″			s
Nov. 29	5	14	17.67	+12	8	57.2	0.403889	0.196175	783
30		13	14.96	12	8	3.7			
Dec. 1		12	11.71	12	7	15.7			
2		11	8.01	12	6	33.2			
3		10	3.93	12	5	56.1	0.404817	0.195574	782
4		8	59.54	12	5	24.5			
5		7	54.93	12	4	58.9			
6		6	50.18	12	4	39.2			
7		5	45.35	12	4	25.6	0.405731	0.196230	783
8		4	40.54	12	4	18.0			
9		3	35.80	12	4	16.4			
10		2	31.20	12	4	20.9			
11		1	26.83	12	4	31.6	0.406631	0.198144	787
12	5	0	22.74	12	4	48.2			
13	4	59	19.06	12	5	11.0			
14		58	15.84	12	5	40.3			
15		57	13.14	12	6	15.9	0.407517	0.201301	793
16		56	11.02	12	6	57.7			
17		55	9.62	12	7	45.9			
18		54	8.99	12	8	40.4			
19		53	9.17	12	9	41.2	0.408390	0.205664	801
20		52	10.22	12	10	48.3			
21		51	12.26	12	12	1.7			
22		50	15.34	12	13	21.5			
23		49	19.51	12	14	47.6	0.409248	0.211168	811
24		48	24.79	12	16	19.9			
25		47	31.30	12	17	58.3			
26		46	39.09	12	19	43.1			
27		45	48.18	12	21	33.9	0.410093	0.217725	823
28		44	58.61	12	23	30.7			
29		44	10.44	12	25	33.3			
30		43	23.73	12	27	41.8			
31	4	42	38.54	12	29	56.2	0.410923	0.225227	838

New Asteroids.—Five new asteroids were discovered by Professor Wolf on a photograph taken at Königstuhl Oct. 22 and a sixth on a photograph taken Oct. 23. The last is perhaps identical with Irma (117). The following were the positions at the time of discovery:

	Königstuhl M. T.			R. A.			Decl.		Daily Motion.		Mag.
		h	m	h	m	s	°	′	s	′	
1900 FM	Oct. 22	11	12.8	1	49	0	+11	02	−48	+2	12.2
FN	"	"	"	1	36	16	+ 9	50	−48	−7	12.8
FO	"	"	"	1	30	24	+ 9	38	−60	−8	12.3
FP	"	"	"	1	37	40	+ 8	26	−36	−4	13.5
FQ	"	"	"	1	50	08	+ 6	03	−48	−6	13.2
FR	Oct. 23	10	17.2	1	47	16	+12	53	−56	−5	.....

Ephemeris of Eros, for Berlin Midnight.

Dates		R. A. h	m	s	Decl. °	′	log *r.*	log Δ	Par.
1901 Jan.	7	2	20	5	+ 35	20.6	0.0636	9.5023	27.6
	8		22	59	34	54.9			
	9		25	55	34	29.2			
	10		28	55	34	3.6			
	11		31	57	33	38.0			
	12		35	2	33	12.4			
	13		38	10	32	46.8			
	14		41	20	32	21.3			
	15		44	33	31	55.8			
	16		47	48	31	30.4			
	17		51	6	31	5.0	0.0587	9.5118	27.1
	18		54	25	30	39.7			
	19	2	57	47	30	14.4			
	20	3	1	10	29	49.2			
	21		4	36	29	24.1			
	22		8	3	28	59.0			
	23		11	32	28	34.0			
	24		15	2	28	9.0			
	25		18	34	27	44.2			
	26		22	8	27	19.4			
	27		25	43	26	54.6	0.0555	9.5271	26.1
	28		29	19	26	30.0			
	29		32	56	26	5.4			
	30		36	34	25	41.0			
	31		40	12	25	16.6			
Feb.	1		43	52	24	52.3			
	2		47	33	24	28.1			
	3		51	14	24	4.0			
	4		54	56	23	39.9			
	5	3	58	38	23	16.0			
	6	4	2	21	22	52.2	0.0543	9.5476	24.9
	7		6	4	22	28.5			
	8		9	47	22	4.9			
	9		13	31	21	41.4			
	10		17	15	21	18.0			
	11		21	0	20	54.8			
	12		24	44	20	31.7			
	13		28	29	20	8.7			
	14		32	13	19	45.9			
	15		35	58	19	23.2			
	16		39	42	19	0.6	0.0550	9.5733	23.4
	17		43	27	18	38.2			
	18		47	12	18	16.0			
	19		50	56	17	53.9			
	20		54	41	17	32.9			
	21	4	58	25	17	10.2			
	22	5	2	9	16	48.5			
	23		5	53	16	27.1			
	24		9	36	16	5.7			
	25		13	19	15	44.6			
	26		17	2	15	23.6	0.0577	9.6035	21.9
	27		20	45	15	2.8			
	28		24	27	14	42.2			
Mar.	1		28	8	14	21.7			
	2		31	49	14	1.4			
	3		35	29	13	41.3			
	4		39	9	13	21.3			
	5		42	49	13	1.5			
	6		46	28	12	41.9			
	7		50	6	12	22.4			
	8	5	53	44	+ 12	3. 2	0.0621	9.6370	20.3

Elements of Asteroid (444) Gyptis.—In *Bulletin Astronomique* for September, 1900, M. L. Fabry gives the following elements of this planet, based upon 71 observations made during April, May, June and July, 1899:

Epoch, May 30.5, 1899, Paris mean time.

$$\begin{array}{rrrrr} & ^\circ & ' & '' & \\ M = & 228 & 23 & 14.3 & \\ \omega = & 151 & 48 & 57.8 & \} \\ \Omega = & 196 & 12 & 20.8 & \} 1899.0 \\ i = & 10 & 13 & 43.5 & \} \\ \varphi = & 9 & 59 & 24.0 & \end{array}$$

$\mu = 769''.234$

$\log a = 0.442632$

Magnitude of planet: $7.7 + 5 (\log \Delta + \log r)$.

GENERAL NOTES.

It is our expectation now to have the January number of this publication ready for mailing about December 20. All articles intended for that issue should be sent on or before the 10th of December.

The Adjustment of the Equatorial.—We are very sorry that our supply of type for our new printing office did not reach us in time to enable us to print in this number all of the second part of Dr. Laves interesting article on the adjustment of the equatorial. The remainder will appear in the next issue. The article as a whole is just what some of our readers have been seeking, for some time in the past.

Military Rank of Professors of the U. S. Naval Observatory.—In our article in the August and September numbers of POPULAR ASTRONOMY we gave the military rank of Professors of Mathematics in the U. S. Navy, and we intended also to give the pay of the same; but the manuscript was mislaid and is appended here. It is from the *Navy Register*, January, 1899. The Navy Personel Bill of 1900 may have changed a very little if at all.

First five years after date of commission, at sea, $2,400; on shore duty, $2,400; on leave, $1,500.

Second five years after date of commission, at sea, $2,700; on shore duty, $2,700; on leave, $1,800.

Third five years after date of commission, at sea $3,000; on shore duty, $3,000; on leave, $2,100.

After fifteen years from date of commission, at sea, $3,500; on shore duty, $3,500; on leave, $2,600.

It will be seen that these salaries compare favorably with those paid to professors of mathematics in many of our wealthy colleges, and have the advantage of being *life* positions. The above table gives the pay of those only on the *active* list.

The Use of the Reseau.—In *Bulletin Astronomique* for September, 1900, M. K. Bohlin gives an account of some interesting researches upon the errors of the réseau, used for measuring stellar photographs, and incidentally brings out the fact that the distortions of the photographic film, which the réseau was originally intended to detect, were almost insensible.

He says: "The réseaux recently constructed by M. Gautier have received a very high degree of perfection, leaving it almost superfluous to determine the errors of the individual lines. In the introduction to the first volume of the *Photographische Himmelskarte, Zone + 31° bis + 40° Deklination,* M. J. Scheiner has given the results of researches on the réseau Gautier No. 47, belonging to the Observatory of Potsdam. The high precision of the réseau is confirmed very strongly by these measures. So M. Scheiner has come to the conclusion that, for the measures of the chart of the sky, the errors of the réseau are quite insensible.

At the Observatory of Upsala they have also made a determination of the errors of the réseau which belongs to that Observatory, and it is reported that this réseau is as perfect as that at Potsdam. For this reason they have referred the measures to two central lines and to four other lines forming, so to speak, the frontier of the réseau. The total number of lines being 50, this reduction of the work necessary to the determination of the réseau is very notable.

"Having begun at our Observatory a determination of the corrections to the measuring apparatus and the réseau by Gautier, we have likewise established the great precision of the réseau employed. We have, however, thought that we should determine the corrections not only to the different lines of the original réseau but also of copies made on photographic plates. So we have measured thus far six plates on which the réseau was photographed in the usual manner, placing the réseau holder at the focus of the photographic objective of the refractor. At the same time with this determination measures have been made on the same lines on the original réseau. The comparison of these two series of observations brings to light a circumstance which does not appear to have been sufficiently considered before."

Here M. Bohlin gives four tables showing the individual measures along two lines of the original réseau and the six copies, in which the mean of the six measures of the original réseau shows an error greater than 0″.05 in only one case, the majority of the errors being only 0.″02 or 0″.03. The means of measures of the six copies on the same lines give slightly larger corrections, the largest being 0″.17. The differences between the individual measures of the six copies are no greater than those of the six measures of the original, but for certain points on the lines there are errors which appear to be systematically common to all the copies. These cannot be due to distortion of the photographic film, which would be likely to affect the same points on different copies with errors of different signs and so be eliminated from the mean of six. They are rather to be traced to some inequality of density or other imperfection in the plate of glass upon which the réseau is ruled and through which the light must pass in making the copy. The largest error of this sort given in the measures is 0″.17, all six copies agreeing in giving an error with the same sign, where the error of the same point in the original réseau is only 0″.01. It would seem better, therefore, to determine the errors of a number of copies of the réseau for practical use than those of the original itself.

M. Bohlin draws the following conclusions from his measures:

1. "The probable errors are very satisfactory and small enough to guarantee the reality of the means.

2. "The corrections to the original réseau are almost insensible.

3. "The corrections to the copies are greater than those to the original and are very irregular.

4. "The probable errors being essentially of the same magnitude in both cases, one may conclude that the real *deformations* of gelatinobromide film on glass (plates of Lumière and Son) *are almost insensible.*"

The last conclusion will be very encouraging to those who are working in the line of celestial photography without the use of a réseau. H. C. W.

Reproductions of Star Charts.—In the supplementary number for 1900 of *Monthly Notices* of the Royal Astronomical Society, Professor Turner gives a valuable note on the "Accuracy of the Star Charts Published by the French Observatories as Reproductions of their Plates for the Astrographic Chart." These charts are large paper sheets, reproducing by heliogravure the long exposure plates on a scale of 2^{mm} to $1'$ (twice that of the original negatives). Professor Turner says that these reproductions are very beautiful but apparently somewhat expensive, and estimates that it would cost each of the observatories taking part in this great work about $50,000 to reproduce their plates in this manner. He questioned, therefore, whether the charts will be of sufficient accuracy to warrant the outlay, and has had a portion of one of the Paris reproductions measured roughly and compared with an Oxford original plate of the same region. The results were unexpectedly gratifying, seeming "to indicate that *we can get star places from paper charts at least as good as those obtained with meridian instruments.*"

In view of the probable accuracy of the charts Professor Turner suggests that no hand work should be allowed in their reproduction, such as the retouching of weak images and the insertion of omitted stars, for this cannot be done with anything like the accuracy of the purely photographic process. H. C. W.

The Collins' Monoplane Telescope.—The writer of the letter appearing in the last issue of POPULAR ASTRONOMY, criticising the Collins' Monoplane Telescope, is evidently under some misapprehension as to the optical arrangement of this new form of telescope.

There are no "oblique rays" to be dealt with, neither are special eyepieces required. The glass employed by the Messrs. Collins, throughout their instrument, is of one kind only—crown of uniform density. A crown and flint combination is not used.

A diagram and further particulars of the optical arrangement of one particular form of the instrument that has been made with aperture of 4 inches, equivalent focus of 10 feet, and but 28 inches total length, including dew cap, is shown in the November number of *Knowledge* (English) page 252.

W. B. MUSSON,
Sec'y of the Toronto Astronomical Society.

The Present Opposition of Eros (433).—P. Stroobant, adjunct astronomer with the Royal Observatory of Belgium at Brussels, has recently prepared a very useful pamphlet of about fifty pages, printed in *French* pertaining to the present opposition of the little planet Eros. In a few introductory pages facts about the discovery and special features of the orbit of the planet are given, with a neat graphical illustration. Then follow a set of useful tables and six

large plates. The tables are essentially those being published from month to month in this journal. The plates give the path of the planet from Oct. 16, 1900 to Jan. 31, 1901, on a scale of about ¾ of an inch to one degree in declination, and about 11/16 of an inch to 4^m in right ascension. This pamphlet will save observers much time in platting the path of Eros.

Eros Observations at Leander McCormick Observatory.—Professor Ormond Stone, director of the Leander McCormick Observatory University of Virginia, Charlottesville, Va., had obtained up to the first of November, 43 sets of positions of the planet Eros, by the aid of the micrometer with the 26-inch refractor, of which about half will be available for parallax determinations.

Eros Observations at Ladd Observatory.—Professor Winslow Upton, director of Ladd Observatory of Brown University, Providence, R. I., reports that micrometer observations have been made with the 12-inch equatorial each clear evening for position, and that special determinations of the position of the little planet, in right ascension, by comparison with neighboring stars, are made each evening and morning. The latter are made by a transit reticle of 11 lines, ruled on glass, and the times recorded on a chronograph. The observations are made in duplicate by Professor Slocum and Professor Upton.

Observations of Eros at Northfield.—At Goodsell Observatory of Carleton College the planet has been observed at each opportunity since Sept. 26. The general plan has been to obtain a photograph with the 8-inch photographic refractor, as early as possible in the evening, then a series of micrometric measures with the 16-inch refractor and finally a second photograph when the planet was near the meridian. Our teaching duties prevent us from working during the whole night, so that it has been thought best for the most part to omit the morning observations. A few morning photographs, however, have been obtained. Early evening photographs were taken Sept. 26, 29, Oct. 9, 10, 11, 12, 16, 18, 19, 23, 24, 25, 26, Nov. 1, 2, 7, 8, 10, 13, 15, 22 and 24; meridian photographs Sept. 26, Oct. 5, 10, 11, 12, 16, 18, 19, 23, 24, Nov. 13; morning photographs, Nov. 13, 14, 22. Micrometric measures were taken from the nearest star of at least the 11th magnitude, Sept. 26, Oct. 10, 11, 12, 16, 17, 18, 19, 23, 24, 25, 26, Nov. 13, 22.

The planet has been bright enough since Oct. 15 to give a measurable image upon the photograph in one minute. We have generally made five exposures on each plate, setting the guiding star in succession upon the four corners of a small rectangle formed by four threads intersecting near the center of the eyepiece. The fifth exposure is a duplicate of the first, but the asteroid having moved in the mean time impresses a second image beside the first, thus making one corner of its rectangle double, while those of the stars are single. It is easy thus to identify the asteroid. On two occasions we have used the asteroid as the guiding star, once by accident, the second time by design, the result being that the stars were all doubled at the corner of the rectangle corresponding to the duplicate exposure, while the images of the asteroid were all round. The elongation of the asteroid image in five minutes is only slight and, being symmetrical, can be measured with the same accuracy as if it were round. We have, however, made our exposures in the following order: at north corner of rectangle 5^m, at east corner 1^m, at south corner 2^m, at west corner 1^m, and duplicate at north corner 5^m; so that the measures of the individual images can be easily compared with the mean of all and thus any systematic errors noticed. H. C. W.

Eros Observations at Chamberlin Observatory, University Park, Col.—Professor H. A. Howe, director of Chamberlin Observatory of the Denver University, reports that forty micrometrical measures of $\Delta\alpha$ and the same number of $\Delta\delta$ are made each clear week night, between Eros and one or more faint companion stars; the observations are divided into two sets, separated by an interval of about one hour, during which Professor Chas. J. Ling connects Eros with two catalogued stars. One of the companion stars is also related certainly to a companion star. Occasionally companion stars are as faint as the 12th magnitude, because no brighter stars are available. Twenty-three nights have been so utilized at Chamberlin Observatory, an excellent start in the parallax work on Eros.

Laying the Corner Stone of the New Allegheny Observatory.—The corner stone of the new Allegheny Observatory was laid October 20, 1900, with appropriate ceremonies. A large audience gathered at Riverside Park, in Allegheny on that occasion which, for some time previously had been in anticipation, in view of its novel and interesting character. During the exercises of this occasion some facts came out that are especially worthy of notice, in relation to the new Observatory and the astronomical work to be pursued by it in the future.

The new building is to cost about $110,000. The material is to be of chiseled granite. The edifice will be over 200 feet long by about 100 feet wide, which will be surmounted at the ends by domes in which the telescopes will be placed.

J. A. Brashear, the head of the well-known firm of makers of optical instruments at Allegheny presided on this occasion and Dr. W. J. Holland, ex-chancellor of the University of Western Pennsylvania made a brief address. Among other apt things he said: "A few weeks ago I was in Italy and met there a British officer. I told him I came from Allegheny. He thought a moment, scratched his head, and said, 'Oh, yes! I know Allegheny; it has a fine Observatory—and by the way isn't there a town called Pittsburg near it?' So you see, the fame of the Allegheny Observatory has spread, and now that we are to have a finer and better one, the world will be brought closer in contact with the little city of Allegheny."

Next followed the chief part of the programme, the historical address by Mr. J. A. Brashear. It is elsewhere printed in full in this number. It was a masterful, apt, fitting and eloquent setting forth of the merits of the theme most dear to his heart. The right man was chosen for this task, and he performed it right royally.

At the close of this address Mr. Brashear deposited the copper box in the niche prepared for it and the great corner stone was lowered to its place. As Mr. Brashear stood upon it he fittingly announced the names of a long list of donors who have made the existence of the new Allegheny Observatory possible. All lovers of astronomy will want to see these names. They follow:

C. G. Hussey, Thomas M. Howe, William Thaw, Mary Thaw, Elizabeth Thaw, J. H. Cooper, H. Childs, W. McClintock, Robert Robb, J. M. Pennock, Felix R. Brunot, W. S. Howe, G. W. Cass, James Park, Jr., B. L. Fahnestock, C. Yeager, D. McCandless, John Dean, W. Bagaley, H. Harper, J. B. Legget, James Patton, Matthew Ferguson, James McCandless, Josiah King, Charles H. Pantser, Alex. Speer, William McKnight, Thompson Bell, J. H. Shoenberger, James Dalzell, O. P. Scaife, W. Dilworth, Isaac Jones, A. Garrison, Laird Campbell, George A. Berry, John A. Wilson, William Wilkins, R. B. Sterling, Joseph Smith, C. W. Ricketson, R. Ashworth, B. Bakewell, R. S. Hays, William Morrison, Henry

Irwin, Louis Jones, W. S. Bissell, B. F. Bakewell, Samuel Gromerly, William Walker, Hay Walker, James A. Wright, N. Holmes, William McCully & Co., A. L. Bollman, J. B. Jackson, Mrs. A. Cosgrove, J. S. Cosgrove, C. Rahm, L. O. Livingstone, James Marshall, J. McD. Crossan and W. F. Johnston.

At the conclusion the spectators were taken all over the basement of the new building and everything was explained to them by Mr. Brashear.

The New Allegheny Observatory.—By kindness of Mr. Brashear and Professor F. L. O. Wadsworth, director of the Allegheny Observatory, we have the privilege of presenting to our readers a view of the new Allegheny Observatory, as photographed from the perspective made by the architect. It is the frontispiece to this number.

The corner stone referred to above was really the cap-stone of the first story, and $22,000 has already been expended in this first story which is to contain the laboratories. The work is now going on for the second story of the building. The outside will be finished in light cream-colored brick and terra-cotta. The dome over the columns will have the 13-inch telescope of the old Observatory mounted in it, and this is to be forever free to students of all educational institutions and to the public under suitable regulations. The great dome will contain the 30-inch equatorial and siderostat telescope, and there will probably be placed in the other dome a special form of reflecting telescope, devised by Professor Wadsworth as a monument to Professor James E. Keeler.

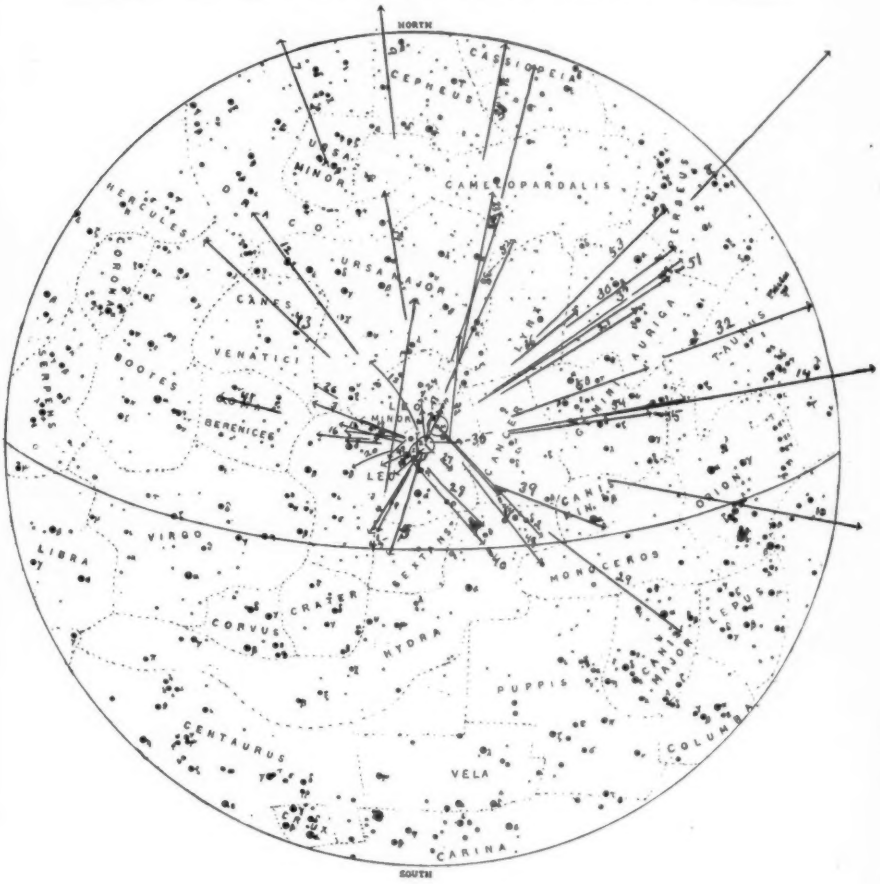
Director Wadsworth is greatly interested in astrophysical research, and he is sparing no pains to secure an Observatory adapted in the very best of modern ways for research in both the old and the new astronomies.

Leonids at Vassar College, Poughkeepsie, N. Y.—The students in the astronomical department at Vassar College, watched for the Leonid meteors on Wednesday and Thursday nights, Nov. 14 and 15. Tuesday night preceding was cloudy. A fairly continuous watch was kept up by different groups of students from 1 to 5 o'clock on the mornings named. Forty-two Leonids were counted on Wednesday and fifty on Thursday. Many other meteors, Geminids and Orionids were also noted; these were not recorded.

The Leonids at Jamaica Plain, Mass.—I observed on the 12th from 2:30 to 5:30 A. M. I saw during this period 5 Leonids and 7 other meteors. The 13th was cloudy until about 6 o'clock. The 14th was cloudy from 12 to 1:30 A. M. My observations were from 12 to 5:20 A. M. During that time I saw 47 Leonids and 31 other meteors. The 15th I did not observe. On the 16th, 4 Leonids and 9 others, making a total of 103 meteors in all, 56 Leonids and 47 others. All these shooting stars with perhaps three exceptions were from radiants in Gemini and Auriga, Leo Minor, δ Ursæ Majoris and one or two from Taurus. The larger number came from Gemini, and the next largest from ι (Iota) Aurigæ. These meteors with five exceptions (one 0.5 magnitude, three of 1st magnitude and an especially brilliant one of (— 2) from δ Ursæ Majoris) were of third magnitude. They were very frequent. So that the number of Geminids, etc., were more numerous than the Leonids. I only recorded meteors that shot into region somewhere near Leo.*

* For want of space the detailed observations in tabular form are omitted. The observations appear to be carefully made.

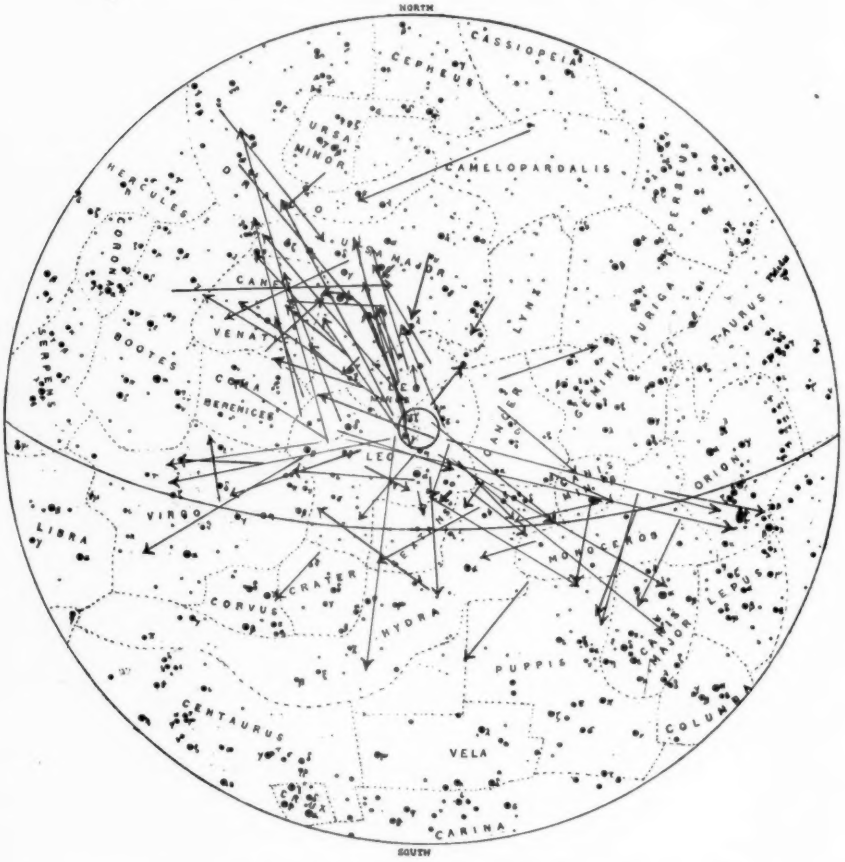
There seemed to be three radiants. The regular radiant and one at γ Leonis and μ Leonis. Nos. 17, 39, 44, 27, 43, 34, 35 and 28 were observed to come from different radiants than the regular one. There was one that started outside of the Sickle, which was marked shooting star, although it may have been a Leonid.



METEORS CHARTED NOV. 12, 14, 16, 1900, AT JAMAICA PLAIN, MASS.

Nos. 2, 8, 10, 12, 13, 18, 19, 37, 44 were brighter than 1st magnitude; Nos. 12, 13 and 44 were especially bright. On Nov. 14, 1900 a very brilliant meteor of —3 magnitude, green, of 3rd magnitude trail shot from δ Ursæ Majoris. On the 16th observations stopped at 4 o'clock A. M. This shower is not as hopeful as those of 1898 and 1899.

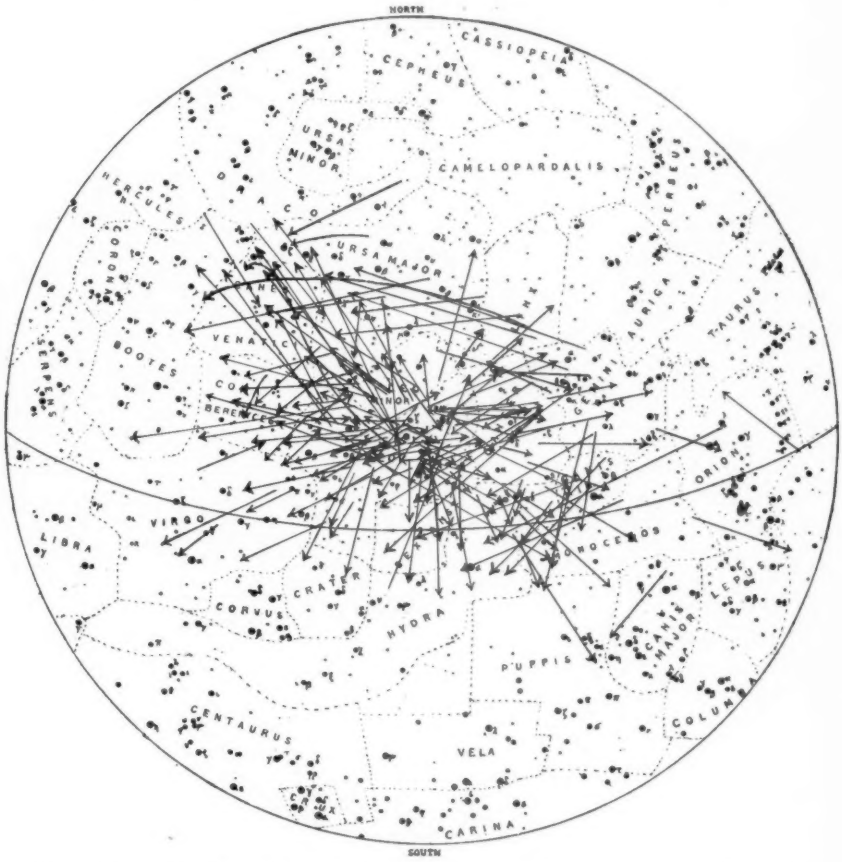
The Leonid Meteors.—Although no remarkable shower has been reported as seen anywhere this year, it is evident that the swarm of Leonids has not all been diverted from its former course far enough to miss the Earth. Watch



METEORS CHARTED NOV. 13, 1900, 12^h TO 18^h CENTRAL STANDARD TIME AT GOODSELL OSBERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.

was kept for the meteors by the astronomy class at Carleton College, Northfield, Minn., on the nights of Nov. 13, 14 and 15 from midnight to morning, with the result that about 30 Leonids were seen on the 13th and on the 14th. The night of the 15th was cloudy except from 12:30 to 13:30 when the portion of the sky near Leo was partly clear. In that interval only one meteor was seen that being a fine Leonid close to the radiant.

The observers being most of them without experience, the radiant indicated is spread over a pretty wide area, but the center is about two degrees southwest from ζ Leonis. As many meteors were seen from other radiants, as from Leo,



METEORS CHARTED NOV. 14, 1900, 12^h TO 18^h CENTRAL STANDARD TIME AT GOODSELL OBSERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.

there being quite a large number from the region of Gemini.

The accompanying charts show the trails platted by about half of the members of the class, duplicates being excluded where it was possible to identify them.

Leonids Observed at Park College, Parkville, Mo.—Professor A. M. Mattoon, director of Scott Observatory, reports observations of the Leonids made on the mornings of the Nov. 14 and 15. On the morning of Nov. 16 it was

cloudy at Parkville from midnight till morning. The morning of the 15th was not satisfactory, on account of passing clouds which continued until 5 o'clock C. S. T. at which time it became perfectly clear.

But few meteors were seen until about 10 minutes after 4 o'clock A. M. From that time until 5:45, 42 meteors were seen and recorded; all but 7 were Leonids.

On Thursday morning (16th) only 8 meteors (due to prevalence of clouds possibly) were seen before 5 o'clock; 22 were counted in the next fifty minutes, all but 3 being Leonids. Observations as compared with those of last year were very unsatisfactory.

Omissions.—Credit should be given for the tables on pages 558 and 559 to *Astronomische Nachrichten* Nos. 3669 and 3670, and for the ephemeris of Eros on page 560 to Bulletin No. 5 of the *Conference Astrophotographic International.*

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Subscription Price to Popular Astronomy in the United States, Canada and Mexico is $2.50 per volume of 10 consecutive numbers. Price per volume of 10 numbers to foreign subscribers $3.00.

All correspondence and all remittances should be sent to

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Northfield, Minn., U. S. A.

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